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AN ANALYSIS OF FIXED WING TACTICAL AIRLIFTER
CHARACTERISTICS USING AN INTRA-THEATER
AIRLIFT COMPUTER MODEL

THESIS

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AFIT/GLM/ENS/91S-50

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The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

AFIT/GLM/ENS/91S-5Ø

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THESIS

Presented to the Faculty of the School of Systems and Logistics

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Master of Science in Logistics Management

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Preface

The purpose of this study was to identify specific tactical airlifter characteristics that, when improved, produce the greatest improvement in tactical airlift capability. This was done by carrying out an experiment using the Generalized Air Mobility Model, a computer simulation of a tactical airlift system. This model allowed the effectiveness of the tactical airlift system to be measured as airlifter characteristics were changed. Characteristics that produced significant changes to the measures of effectiveness were then identified.

I became interested in this topic primarily because the Royal Australian Air Force has been considering a number of different aircraft as possible replacement tactical airlifters. This research was an attempt to identify the most important tactical airlifter characteristics, and so provide some insight for a future aircraft selection process. For this reason, the scenario chosen for the experiment was Central America. Of the three scenarios available to use with the model, the Central American scenario most closely matched the environment within which the Australian Defence Force might possibly be operating in a future conflict.

I wish to express my appreciation to my advisor, Maj Paul Auclair, for his continued support throughout this effort. His expertise, knowledge, and experience in operations research helped me many times in progressing from an initial formless idea to the final product. I would also like to thank Steven J. Wourms of the Directorate of Advanced

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Finally, I'd like to thank my wife, Janine, and my children, Alissa and Christopher, for their patience and understanding during the many days and nights when I was tied to my desk with work.

Paul Pappas

Table of Contents

		Page
Preface		ii
List of Figures		vii
List of Tables		viii
Abstract		xi
I.	Introduction	1
	Tactical Airlift in the USAF	1
	The Airland Battle	2
	General Issue	3
	Problem Statement	5
	Research Question	6
	Research Objective	6
	Scope	6
	Summary	6
II.	Background	8
	Measures of Effectiveness	8
	The Advanced Transport Technology Mission Analysis (ATTMA)	10
	Summary	13
III.	Generalized Air Mobility Model Overview	14
	Introduction	14
	The Generalized Air Mobility Model (GAMM)	15
	GAMM Simulation Elements	15
	GAMM Simulation Overview	18
	GAMM Scenario Definition	20
	Selection of Scenario	21
	The Central American Scenario	22
	Summary	27
IV.	Methodology	28
	Introduction	28
	Weakness of One-Variable-at-a-Time Strategy	28
	Selection of an Experimental Design	31
	Selection of Variables	34
	Defining Measures of Effectiveness	37
	Specification of Variables	38

Page

Standard GAMM Initializing Parameters 42
Stochastic Modeling 43
Determining the Required Number of Replications . 44
Modification of Scenario Files 46
Analysis of the Main Effects of a Two Level Factorial Design 48
Analysis of the Interaction Effects of a Two Level Factorial Design 49
Yate's Algorithm 50
Analysis of the Results of a Two Level Factorial Experiment 51
Development of a Regression Model 53
Development of a Parsimonious Model 55
Identification of Significant Aircraft Characteristics 56
Summary 57

V. Verification and Validation 58

Introduction 58
Verification of GAMM 58
Validation of GAMM 60
Event Validation of GAMM 61
Summary 64

VI. Experimental Findings and Analysis 66

Calculation of the Required Number of Replications 66
The Required Number of Replications - Interpretation of Results 68
Experimental Results 71
Transformation of Data 74
Identification of Significant Terms 75
Identification of Relevant Terms 78
Comparison of Transformed Results 81
Interpretation of Results 82
Analysis of the Interaction Term 88
Summary 89

VII. Conclusions and Recommendation 90

Summary of Experiment 90
Results 91
Implications of these Results 92
Recommendations for Further Research 92

Appendix A: GAMM Airlifter Characteristics - Baseline C-130H 95

Appendix B: Airlift Jobs for Central American Scenario . . . 96

	Page
Appendix C: GAMM Initialization Sequence - Baseline Parameters	97
Appendix D: Design Matrices for Interaction Terms	100
Appendix E: Results and Calculations for the Number of Required Replications	108
Appendix F: Random Number Seeds used for Experimental Runs .	112
Appendix G: Yate's Algorithm - Calculations for Estimate of Effect	113
Appendix H: Difference Between Two Averages - Calculations for Estimate of Effect and Standard Error	125
Appendix I: Yate's Algorithm - Calculations for Estimate of Effect for Transformed Results	128
Appendix J: Difference Between Two Averages - Calculations for Estimate of Effect and Standard Error for Transformed Results	140
Appendix K: Experimental Results Transformed to Natural Logarithms	143
Appendix L: Analysis of Initial Regression Equations	145
Appendix M: Analysis of Reduced Regression Equations	153
Bibliography	168
Vita	171

List of Figures

Figure		Page
1.	GAMM's Transportation System	17
2.	Offensive Operations in the Central American Scenario .	23
3.	Central American Flot Locations	24
4.	Central American Job Occurrences by Delivery Time . .	25
5.	Tonnage Required by Day	26
6.	Cumulative Required Tonnage	26
7.	Results of a One-at-a-Time Experiment	30
8.	Yate's Algorithm - 2^3 Factorial Experiment	51
9.	Initial Regression Equations	77
10.	Parsimonious Regression Equations	80
11.	Interaction Effect - Ratio On Time	84
12.	Interaction Effect - Ratio Delivered	84
13.	Interaction Effect - Total Sorties Flown	85
14.	Interaction Effect - Productive Sorties Flown	86
15.	Interaction Effect - Total Flight Hours	87
16.	Interaction Effect - Productive Flight Hours	87

List of Tables

Table		Page
1.	GAMM Airlifter Functional Parameter Sets	36
2.	Definition of Variables - Two Level Factorial Design .	4Ø
3.	2^6 Two Level Full Factorial Design Matrix	41
4.	GAMM Event Validation - Expected Sorties Generated . .	63
5.	GAMM Event Validation - Actual Sorties Generated . . .	63
6.	GAMM Model Replications - Results of Ten Independent Runs	67
7.	Extract of Calculations for Determining the Required Number of Replications	69
8.	Experimental Results: GAMM Cental American Scenario .	72-73
9.	Summary of ANOVA Tables for Initial Regression Equations	76
1Ø.	Summary of ANOVA Tables for Parsimonious Regression Equations	79
11.	Comparison of Results for Ratio On Time	82
12.	Summary of Significant Airlifter Characteristics - Central American Scenario	91
13.	Two-Factor Interaction Design Matrix	1ØØ-1Ø1
14.	Three-Factor Interaction Design Matrix.	1Ø2-1Ø3
15.	Four-Factor Interaction Design Matrix	1Ø4-1Ø5
16.	Five-Factor and Six-Factor Interaction Design Matrices	1Ø6-1Ø7
17.	Calculation of Number of Runs Required - One Percent Accuracy	1Ø8
18.	Calculation of Number of Runs Required - Two Percent Accuracy	1Ø9
19.	Calculation of Number of Runs Required - Three Percent Accuracy	11Ø

Table		Page
20.	Calculation of Number of Runs Required - Four Percent Accuracy	111
21.	Yate's algorithm, Results for Ratio On Time	113-114
22.	Yate's algorithm, Results for Ratio Delivered	115-116
23.	Yate's algorithm, Results for Total Flight Hours . . .	117-118
24.	Yate's algorithm, Results for Total Sorties Flown . . .	119-120
25.	Yate's algorithm, Results for Productive Flight Hours .	121-122
26.	Yate's algorithm, Results for Productive Sorties Flown	123-124
27.	Summary of Estimated Effects of Conditions on the Ratio of Cargo Delivered	125
28.	Summary of Estimated Effects of Conditions on the Number of Hours Flown	126
29.	Summary of Estimated Effects of Conditions on the Number of Sorties Flown	127
30.	Yate's algorithm, Results for Ratio On Time - Transformed to Natural Logarithms	128-129
31.	Yate's algorithm, Results for Ratio Delivered - Transformed to Natural Logarithms	130-131
32.	Yate's algorithm, Results for Total Flight Hours - Transformed to Natural Logarithms	132-133
33.	Yate's algorithm, Results for Total Sorties Flown - Transformed to Natural Logarithms	134-135
34.	Yate's algorithm, Results for Productive Flight Hours - Transformed to Natural Logarithms	136-137
35.	Yate's algorithm, Results for Productive Sorties Flown - Transformed to Natural Logarithms	138-139
36.	Summary of Estimated Effects of Conditions on the Ratio of Cargo Delivered - Results Transformed to Natural Logarithms	140
37.	Summary of Estimated Effects of Conditions on the Number of Hours Flown - Results Transformed to Natural Logarithms	141

Table		Page
38.	Summary of Estimated Effects of Conditions on the Number of Sorties Flown - Results Transformed to Natural Logarithms	142
39.	Experimental Results Transformed to Natural Logarithms: GAMM Central American Scenario	143-144

Abstract

This study used computer simulation to identify which tactical airlifter characteristics most significantly affected tactical airlift capability in a given scenario. The Generalized Air Mobility Model was used to simulate a tactical airlift system. Aircraft characteristics within the model were grouped into six variables. A 2^6 two level full factorial experimental design was used to assess the effect of changes in aircraft characteristics on the effectiveness of the tactical airlift system. Yate's algorithm was used to identify significant terms based upon the results of the factorial experiment. These significant terms were used to develop a parsimonious regression model that represented the response function of the experimental variables. The variables remaining in the regression model represented the tactical airlifter characteristics that most significantly affected the capability of the tactical airlift system. Only one scenario was used in the experiment: Central America. This scenario was characterized by a tropical mountainous environment, poor infrastructure, a limited number of major airfields, and many short unprepared airfields. Two groups of tactical airlifter characteristics were found to significantly affect capability of the tactical airlift system in this scenario: the size of the aircraft's cargo bay, and the aircraft's ability to operate on unprepared surfaces.

AN ANALYSIS OF FIXED WING TACTICAL AIRLIFTER CHARACTERISTICS

USING AN INTRA-THEATER AIRLIFT COMPUTER MODEL

I. Introduction

In the Johnson-McConnell Agreement of 1966, the responsibility for all fixed wing airlift in the U.S. Armed Forces was given to the U.S. Air Force (USAF), and so the Military Airlift Command (MAC) became the primary provider of airlift for the Armed Forces (19:8). MAC has two major roles: strategic or inter-theater airlift, and tactical or intra-theater airlift.

Tactical Airlift in the USAF

Strategic airlift involves the movement of personnel, supplies and equipment, to, from, or between theaters of operations. Tactical airlift involves such movements within a designated theater of operations. Tactical airlift usually involves movement over much shorter distances than strategic airlift (11:8).

For tactical airlift, the USAF defines five general mission categories:

1. Deployment. Deployment is the movement of forces to their initial area of operation in theater.
2. Employment. Employment is the movement of forces around a theater after of their initial deployment.
3. Sustainment. Sustainment is the movement of replacement personnel and supplies in support of deployed forces.

4. <u>Retrograde</u>. Retrograde is the use of aircraft on the return leg of a deployment mission, such as for evacuees or enemy prisoners of war.

5. <u>Air Evacuation.</u> Air Evacuation usually requires a specially configured aircraft (18:8-9).

In MAC, tactical airlift is currently carried out by Lockheed C-130 Hercules aircraft. The C-130s will soon be augmented by the introduction of the McDonnell Douglas C-17. While the C-17 will have short field performance similar to the C-130, it is not intended to replace the C-130. The C-17 was designed as a long range, heavy lift cargo transport. It is intended primarily to provide inter-theater airlift of outsize loads, such as tanks and infantry fighting vehicles, directly into airfields in potential conflict areas (12:467).

The Airland Battle

The primary objective of tactical airlift is to provide the user, which is usually the Army, with the capability to carry out a mission when there are no other means available to do the job. One of the most important reasons for the use of tactical airlift is speed of response. Tactical airlift also provides the Army with increased mobility without reliance upon Ground Lines Of Communication (GLOC). It affords a degree of manoeuver that may otherwise be impossible due to the lack of roads, rail lines or major airfields within a theater of operations (1:161; 18:5-6).

Since the U.S. Army formalized the Airland Battle doctrine, the concept of the battlefield has changed. Instead of a single line on the map designating the Forward Line Of Troops (FLOT), the Airland Battle

will consist of nonlinear battlefields with some Army units carrying out deep attacks on second echelon units while others simultaneously engage first echelon units (7:3,8). Those units carrying out the deep attacks will be heavily dependent on tactical airlift for the initial assault and for continued resupply because the Ground Lines Of Communication will be either nonexistent or uncertain (11:6).

The Airland Battle will require tactical airlift to operate up to and beyond the FLOT in the support of ground forces. This environment will present a significantly greater threat to tactical airlift operations than has previously existed. The increased threat highlights the vulnerability of the C-13Ø, which was designed with a wet wing and has no provision for radar warning receivers, electronic countermeasure pods or flare/chaff dispensers. (13:43-44)

General Issue

The C-13Ø aircraft is the backbone of intra-theater tactical airlift for the U.S. Armed Forces and the military forces of 57 countries around the world. Over 18ØØ C-13Ø aircraft have been produced (12:446).

The original C-13Ø was designed to a specification issued by the U.S. Tactical Air Command (TAC) in 1951 (12:446). With the exception of a number of C-13Øs that have undergone a stretch modification of their fuselages to increase the size of the cargo bay, most C-13Øs flying today have essentially the same tactical airlift capabilities as the original C-13ØA aircraft.

Even though it is still an effective tactical airlifter, the C-13Ø is based on a 4Ø year old design that did not anticipate recently

developed requirements. The adoption of the Airland Battle doctrine by the U.S. Army has significantly changed the environment within which tactical airlift will be operating. A tactical airlifter suited to the demands of the new battlefield environment should be considered to replace the C-130. It should incorporate survivability and vulnerability improvements to successfully operate in the modern tactical environment, and use new technology to improve upon the C-130's tactical airlift capabilities. However, while the development of a replacement for the C-130 was discussed by the National Military Airlift Subcommittee of the U.S. House Armed Services Committee as long ago as 1970, no replacement for the C-130 is currently available (13:44).

Before a new aircraft can be designed, an assessment of tactical airlift requirements and capabilities is required. "Looking back at the state of mobility analysis in 1983, there was a glaring imbalance between our ability to evaluate strategic mobility systems and our ability to assess tactical mobility requirements and capabilities" (6:2-2).

The 1981 Congressionally Mandated Mobility Study (CMMS) was able to define strategic deployment requirements and set a mandated minimum strategic airlift capability of 66 million ton miles per day. However, no similar target was defined for tactical airlift. In order to better define tactical airlift requirements, two major studies were begun in 1983: the Qualitative Intra-theater Airlift Requirements Study (QITARS) and the Worldwide Intra-theater Mobility Study (WIMS) (11:7).

> QITARS, completed in 1985, defines wartime missions that support AFM 1-1, the basic airlift doctrine of deployment, employment and sustainment of combat forces. WIMS, completed in 1988, defines

> the requirements for all modes of transportation within a theater that includes airlift. (11:7)

Both studies concluded that there was a significant shortfall in existing intra-theater airlift capability (11:7).

To better define tactical airlift capabilities, the USAF Aeronautical Systems Division (ASD) initiated the Advanced Transport Technology Mission Analysis (ATTMA) project in 1986. The primary aim of the ATTMA project was to investigate the relative merits of new tactical airlifter concepts. The evaluation was based upon a number of different aircraft options including "short takeoff and landing (STOL), very short takeoff and landing (VSTOL), and low observable systems including large, medium, and small cargo compartments (relative to the current C-130 aircraft)" (20:8).

A number of new system concepts have been developed and continue to be evaluated as a result of the ATTMA project. In addition, a deficiency analysis of the C-130 was carried out as part of the ATTMA project to determine how changes to individual C-130 characteristics affected tactical airlift capability (24).

Problem Statement

Although the ATTMA deficiency analysis looked at a number of individual characteristics and combinations of characteristics, a full analysis of tactical airlift aircraft characteristics has never been carried out. Such an analysis would determine which specific characteristics or combination of characteristics of the C-130 most significantly affect its tactical airlift capability.

Research Question

What specific set of tactical airlifter characteristics result in the greatest improvement in tactical airlift capability?

Research Objective

The primary objective of this research will be to use computer simulation to investigate how changes to specific aircraft characteristics affect tactical airlift capability, given a specific theater of operations and a specified set of tactical airlift requirements. Answers to the following questions will be sought:

1. How is the tactical airlift capability of fixed wing aircraft measured?
2. What individual aircraft characteristics significantly affect tactical airlift capability when changed?
3. What combination of aircraft characteristics, when changed, results in the greatest improvement in tactical airlift capability?

Scope

The scope of this research will be limited to a study of the capabilities of the tactical airlift assets using the scenario described in Chapter III. Although changes from the original scenario will be discussed, no analysis or validation of the scenario is intended.

Summary

This chapter has defined the role of tactical airlift in the USAF and the importance of the C-130 to that role. It highlighted the fundamental reason for a C-130 replacement: its 40 years old design did

not anticipate the demands of the modern tactical operating environment associated with the U.S. Army's Airland Battle concept.

This chapter also listed previous studies related to tactical airlift capabilities and requirements. It noted that no previous study had undertaken a full analysis of aircraft characteristics and their effect on tactical airlift capability. The research objectives outlined will assist in identifying which characteristics significantly affect tactical airlift capability.

II. Background

A variety of measures of effectiveness have been used by MAC and by previous tactical airlift studies to assess the capability of tactical airlifters. In this chapter, these measures of effectiveness will be reviewed. In addition, a summary of the most recent USAF study of tactical airlift capability, the ATTMA project, will be presented.

Measures of Effectiveness

The current measures that MAC uses to determine the capability and effectiveness of its tactical airlifters are the same measures used to measure the capability and effectiveness of its strategic airlift aircraft. Specifically, the MAC measures are:

1. Tons of cargo moved within a certain period, such as tons per day,
2. Average aircraft flying time per day, which is also called utilization rate (UTE Rate),
3. Departure reliability, that is, being able to depart on a scheduled departure time, and
4. The number of hours flown to hours scheduled to be flown (5:4).

Many previous studies have indicated that these measures are not very useful in measuring either the capability or effectiveness of tactical airlift (5:3-5; 15:22; 18:22; 24:Sec 3.1 1-2).

Of the five general missions of tactical airlift, only sustainment involves the movement of bulk cargo. The other missions are primarily concerned with the movement of personnel and rolling stock (18:9). Tons per day is not a very useful indicator of the effectiveness of tactical

airlift. Operational limitations often require missions to be flown with half empty aircraft (18:22). In fact, the WIMS study found that for tactical transport in general, "tons per day was not an adequate measure of requirements or capabilities for any mode" (15:22).

UTE rates are also a poor measure of tactical airlift effectiveness because tactical airlift missions are "characterized by multiple sorties of short range and duration, leading to low daily aircraft utilization rates" (11:7).

The current measures of tactical airlift capability used by MAC are primarily efficiency measures that do not take into consideration the ability of tactical airlift to meet the user's needs. "The fact that tactical requirements are often determined by the user as a result of changing combat situations makes response to these requests more important than the need to efficiently use the aircraft" (5:5).

A number of studies have tried to produce a better set of measures of tactical airlift capability. WIMS divided the requirements of the intra-theater workload into three categories, according to the items being carried, with each category having its own measure:

1. Dry Cargo: tons; ton-miles,
2. Petrol, Oil and Lubricants (POL): barrels; barrel-miles, and
3. Passengers: passengers; passenger-miles (15:19).

Wargaming simulations carried out by LTV's Mission Analysis Center and the McDonnell Douglas Aircraft Company considered that the effectiveness of tactical airlift could only be measured by assessing the overall force effectiveness in a given scenario (14:1). Some of the measures that were used to assess force effectiveness included:

1. the size of the surviving and attrited forces,
2. the relative combat power between the two opposing forces,
3. the depth of penetration and ground lost or taken, as measured by the Forward Line of Troops (FLOT), or
4. a record of objectives achieved (14:17).

This type of study required that a specific scenario be simulated, and the results recorded. Subsequent simulations of the same scenario using different tactical airlift forces would produce different results (14:18-27). The differences in the results could then be attributed to changes in the composition of the tactical airlift forces.

The ATTMA project also used a computer simulation to "analyze the effectiveness of airlifters in representative theater airlift wartime scenarios" (24:Sec 3.1 1). The ATTMA analysts determined that tons per day and ton-miles per day were not suitable measures of effectiveness for intra-theater airlift, and that "theater effectiveness is much more a function of timeliness, quantity, and survivability of cargo" (24:Sec 3.1 2). A number of measures were used in the ATTMA project to assess the effectiveness of tactical airlift, including UTE Rate, tons delivered, tons delivered on time, delivery time, productivity, and aircraft attrition (24:Sec 3.1 3).

The Advanced Transport Technology Mission Analysis (ATTMA)

The ATTMA project was the most comprehensive analysis of tactical airlift capability ever carried out by the USAF. Its purpose was to "support Headquarters, Military Airlift Command (MAC) in developing data to support the preparation of a Statement of Operational Need for its next generation tactical airlifter" (20:1). The project developed

> a comprehensive database highlighting system needs, technology opportunities, and potential solution concepts; an evaluation of those solution concepts which were developed; and a technology development plan capable of allowing the timely development of the identified concepts. (2Ø:2)

The project began with "an extensive needs analysis that evaluated the baseline force of intra-theater airlift performing representative jobs in likely environments containing projected threat and defined infrastructure" (2Ø:4). The likely environments were developed into three descriptive scenarios, Europe, Southwest Asia and Central America, with each scenario representing significantly different threat levels, infrastructure, airlift tasks and geographical regions.

As mentioned previously, the main tool used to carry out the required analysis was a computer simulation. Prior to ATTMA, there were two main computer models that represented intra-theater airlift: the Tactical Airlift System Comparitive Analysis Model (TASCAM) and the Scenario Unrestricted Mobility Model for Intra-theater Simulation (SUMMITS). TASCAM was designed to represent the intra-theater airlift logistics system and considered "maintenance problems, available ramp space, on/offload times, and scheduled airlift based on priorities" (5:9). SUMMITS is an intra-theater scheduling model that was used extensively in WIMS to determine intra-theater airlift requirements (15:13).

Neither of these models were suitable for the analysis required to be carried out in ATTMA and so a new model was developed: the Generalized Air Mobility Model (GAMM). GAMM was designed to model a tactical airlift system, and focuses on the movement of tactical airlift loads from source to destination. By contrast, in wargaming simulations

such as those carried out by the LTV Mission Analysis Center, the tactical airlift system is one of many factors influencing the overall outcome. GAMM measures the effectiveness of a tactical airlift system to meet the operational requirements of a given scenario. It does not purport to assess the outcome of a campaign based on tactical airlift or any other factor (17:1).

The initial analysis carried out using GAMM was the assessment of a baseline tactical airlift force, consisting of a mixed fleet of C-130s and C-17s, in each of the three theaters. Once the baseline force had been evaluated, a deficiency analysis was carried out. The deficiency analysis was intended to identify specific C-130H airlifter-related problems that prevented the tactical airlift system from achieving the required level of throughput (24:Sec 3.4 1). The majority of the runs for the deficiency analysis were carried out by changing either one or two characteristics of the C-130H at a time and then assessing how these changes affected the throughput of the airlift system. In addition, a small number of runs were carried out where six to eight C-130H characteristics were dramatically and simultaneously improved.

The deficiency analysis concluded that, for the Central American scenario, a single significant problem existed with the C-130H: its poor landing gear performance limited the aircraft's ability to use the many unprepared airfields available in that region (24:Sec 3.4 49). For the European and Southwest Asian scenarios, the conclusions were that "no single deficiency exists for the C-130H, which if corrected, would make a dramatic improvement in the ... airlift system's effectiveness" (24:Sec 3.4 18,33).

In all three scenarios, the greatest improvements in system effectiveness were achieved by the "super planes" which had six to eight characteristics dramatically improved (24:Sec 3.4 18,33,49).

Summary

This chapter reviewed the measures of effectiveness that have been used to assess the capability of tactical airlift. While most of the tactical airlift studies carried out agree that the measures used by MAC are not suitable, there is no consensus as to which measures are more useful.

In addition, this chapter briefly reviewed the ATTMA project, and the deficiency analysis that was carried out as part of ATTMA. The conclusions of the deficiency analysis were that, with the exception of the landing gear limitation in Central America, there was no single deficient characteristic of the C-13Ø, which, if corrected, could significantly improve the airlift system's effectiveness. However, by dramatically improving six to eight characteristics at the same time, a significant improvement could be achieved.

III. Generalized Air Mobility Model Overview

Introduction

The purpose of this research is to identify which characteristics of tactical airlift aircraft are of greatest importance in determining tactical airlift capability.

This cannot be done by an analysis of past campaigns because each campaign had distinctly different tactical airlift requirements that were determined by the geographical location of the campaign and the intensity of the combat during the campaign. In addition, the significant differences in aircraft performance between tactical airlifters used in past campaigns confound any attempt to isolate the effect of individual aircraft characteristics on the efficacy of tactical airlift during any particular campaign.

Similarly, the capabilities of individual tactical airlift aircraft cannot be used to determine how effective those aircraft will be as part of a tactical airlift system in a given situation. Performance measures, such as the amount of cargo or the number of fully equipped troops that can be carried, only define the limits of an aircraft's capabilities. Tactical airlift requirements and the operational limitations of a given scenario are not taken into account by aircraft characteristics.

However, by using computer simulation to model a tactical airlift system with a given set of tactical airlift requirements, it may be possible to identify how changes in aircraft characteristics can affect tactical airlift capability for a particular scenario or setting. Three

major tactical airlift models have already been mentioned: TASCAM, SUMMITS and GAMM. Of these, only GAMM has sufficient fidelity to evaluate the effects of changes in tactical airlifter characteristics.

The Generalized Air Mobility Model (GAMM)

GAMM was developed by the General Research Corporation (GRC) for the Directorate of Advanced Systems Analysis, ASD/XRM, Aeronautical Systems Division at Wright-Patterson Air Force Base.

The GAMM program operates on Digital Equipment Corporation (DEC) MicroVAX II computers that have at least 6 Megabytes of RAM and 5Ø Megabytes of disk storage capacity. The program was written using Simscript II.5 and FORTRAN 77 (DEC Version 4.4) (9:Sec 1-5).

GAMM is a "Monte-Carlo simulation of an airlift transportation system" (9:Sec 1-3) that

> simulates the movement of cargo by an intratheater airlift system. It requires information concerning the cargo to be moved, the transportation system network, and the characteristics of the airlifters to be used ...In addition to airlifter flights, GAMM simulates airlifter ground operations, airdrops, movement of cargo by Army trucks and the survivability/vulnerability of the cargo in its various modes of transportation. (17:1)

As part of the ATTMA project, GAMM has been used for the deficiency analysis of the C-13ØH airlifter mentioned previously, and is currently being used by ASD/XRM, MAC and three airlifter airframe contractors for the evaluation of "conceptual airlifter designs" (17:1).

GAMM Simulation Elements

There are four major elements to the GAMM simulation: the airlifters, the airlift jobs, the airbases, and cargo entry/delivery (E/D) sites. Each of these elements is discussed below.

Airlifter Definition. The airlifters used in the simulation are defined by 69 parameters. These parameters include takeoff and landing performance, cargo compartment size, reliability and maintainability, ground operation factors and attrition factors (9:Sec 2-5 to 2-8). An example of the baseline C-130H model parameters is contained in Appendix A.

Airlift Jobs. Each airlift job defines the type and amount of cargo that is required to be moved by the transportation system. The specifications for the jobs carried out within the Central American scenario are contained in Appendix B (22:Sec 4-8). In addition to a description of the individual movement items, the airlift job contains the details of the E/D sites, entry and delivery times and the job priority (9:Sec 2-9).

Airbases. Airbases in GAMM are defined by their geographic and physical characteristics such as latitude and longitude, elevation, and runway length, and also by airbase attack characteristics such as the number of attacks on the airbase per day (9:Sec 2-9 to 2-12).

Entry/Delivery (E/D) Sites. Airlift jobs originate or terminate at an E/D site. E/D sites are typically linked to a number of airfields. The links define the transhipment time and order of preference between the E/D site and each of the associated airfields (9:Sec 2-12).

The information about these elements is contained in two input files that are required by GAMM in order to run a simulation. Airlifter characteristics, airbase characteristics and the E/D site information is

contained in a scenario file. All the airlift jobs are contained in a jobs file.

Cargo Movement Within GAMM. GAMM represents the movement of cargo from an airlift job in the following manner. Cargo enters the simulation at an entry site and is then moved along a transshipment arc to an originating airbase. If no aircraft are available, the cargo awaits the arrival of an aircraft. When an aircraft is available, the cargo is transported to a receiving airbase. The cargo is then transshipped to the delivery site. This is represented in Figure 1.

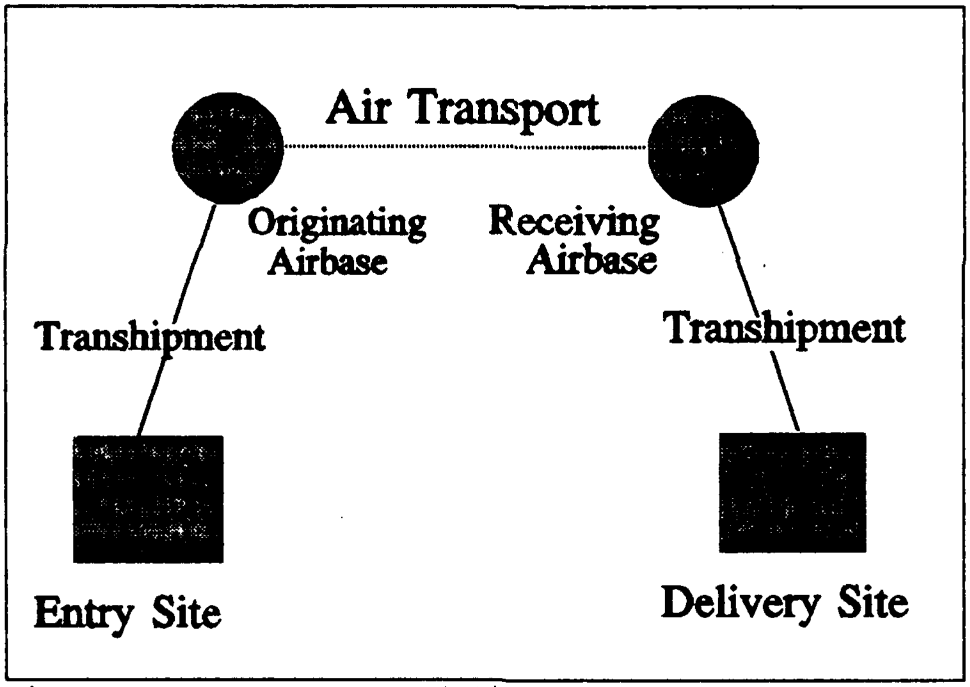


Figure 1. GAMM's Transportation System (9:Sec 3-1)

The movement of cargo along transhipment arcs is not modeled with great accuracy in GAMM (9:Sec 3-7). For each link, the transport mode used for cargo transhipment is defined by specifying the travel time that it takes the cargo to move along the transhipment link. As well as

the actual movement time, the travel time also includes the time it takes to prepare cargo for transhipment, and the time to load and unload the cargo using the predetermined transport mode (9:Sec 3-8). If transhipment is carried out primarily by helicopters, then the travel time will reflect the total transit time required to move the cargo by helicopter. If transhipment is primarily by trucks, then the travel time will be set accordingly.

GAMM assumes that there is always a sufficient supply of transport equipment available to move the cargo along the transhipment links. Any blockages or significant delays that occur in delivering cargo will be due to bottlenecks or limitations of the air transport system, and will not be caused by limitations in the transhipment phase.

GAMM Simulation Overview

The GAMM simulation begins with all airlifters at their home bases. As airlift jobs enter the simulation, a scheduling algorithm begins to schedule airlifters for missions, initially scheduling airlift jobs from originating airbases that have airlifters available. Once all these jobs have been scheduled, the scheduler relocates remaining airlifters to airbases that have a backlog of jobs and either insufficient or no airlift capacity available (9:Sec 3-2).

For each originating airbase, airlift jobs can be scheduled to depart either according to the highest priority or according to the largest weight of cargo. There are nine priority levels, 1 to 9, with priority level 1 being the highest. If a priority scheduling factor is set during the initialization of the simulation run, all jobs with a priority level higher than this factor will be scheduled in order of

their priority. All other jobs will be considered of equal priority, and will be scheduled according to their weight. If no priority scheduling factor is set, all jobs will be scheduled according to their weight (9:Sec 3-2).

In a similar manner, if a priority scheduling factor has been set, aircraft are relocated to originating airbases with the highest priority jobs. If all available airlift jobs have a priority less than or equal to the priority scheduling factor, or if no factor is set, aircraft are relocated to the airbase that has the largest backlog, by weight, of cargo (9:Sec 3-2).

Before an aircraft is loaded, the program checks the airfields associated with the delivery site of the job, in order to determine which airfield can be used by the airlifter, and how much cargo can be carried into that airfield. The airfields are checked in the order of preference specified in the links for each E/D site. The program will select the first suitable airfield to use as the receiving airbase. If no suitable airbase can be chosen, that job is blocked from further progress because it cannot be delivered. In a similar manner, prior to an aircraft being relocated to or otherwise being loaded at an originating base, a calculation is done to determine the useful payload that can be carried by the aircraft taking off from that base. If no useful payload can be carried, that cargo is blocked because it cannot be picked up (9:Sec 3-2 to 3-3).

Once the program has determined that the load can be delivered, the aircraft is loaded. Two loading methods are available: weight-and-

volume loading or weight-only loading. Either one of these methods can be selected during the initialization of the program (9:Sec 3-3).

At the receiving base, the cargo is unloaded for transshipment to the delivery site, and the aircraft is serviced. Once the servicing has been completed, the aircraft is ready to be scheduled for another airlift job (9:Sec 3-4).

Attrition. One important aspect of GAMM is its ability to simulate losses due to combat. Cargo can be destroyed during transshipment. Airbases can be attacked and runways damaged. Aircraft can be damaged or destroyed during flight or while on the ground. In addition, aircraft may break down and require maintenance. Within the program, cargo that is destroyed is reordered and damaged runways are repaired, although both of these take some time and may result in a job not being completed on time. However, aircraft that are destroyed during the simulation are not replaced.

GAMM Scenario Definition

The scenarios used in GAMM are based on the following assumptions:

1. The scenarios could occur between 1995 and 2010.
2. No nuclear, chemical or biological weapons are used in the war.
3. The airlift jobs were defined irrespective of airlift resources available to accomplish the job, but are representative of the types of jobs that airlifters will be required to perform.
4. The Army AirLand Battle Doctrine and Army 21 concepts were used (24:Sec 3.1 2). (Army 21 is a concept document that attempts to define the Army's future war fighting concepts (11:4).)

Descriptive scenarios for Europe, Southwest Asia and Central America were chosen to provide a "spectrum of logistics infrastructure" and a "spectrum of operational conditions" (23:10). Each scenario was initially developed as a qualitative description of the pre-hostility situation and the notional conflict that takes place (22:Sec 2-1 to 2-3). This qualitative description provided the background from which the scenario environment and tactical airlift requirements were established. Once these had been established, a quantitative description of the scenario was developed, including specific airlift jobs (24:Sec 3.2 5; 22:Sec 4-1 to 4-42).

Each scenario represents a conflict that lasts 30 days, and the airlift jobs have been defined irrespective of the threat environment, mode of delivery, or resources available (24:Sec 3.2 1).

Selection of Scenario

Of the three scenarios available, the Central American scenario was selected. One reason for selecting this scenario was that the deficiency analysis had been able to identify the landing gear performance of the C-130 as being a significant deficiency in this scenario. By using Central America, the findings from this experimental analysis should support the results of the deficiency analysis.

In addition, the Central American scenario has many similarities to the type of conflict that the Australian Defence Forces might have to face within Australia's Region of Direct Military Interest (RDMI). Specifically, one of the likely contingencies that could require the involvement of the Australian Defence Forces in the future is an escalated low level conflict. "Escalated low level conflict could

spring full-blown onto Australia with little or no warning, bringing attacks of a more conventional nature ... against Australia" (1:63).

The terrain and infrastructure of the Central American theater is very similar to the type of terrain and infrastructure in Northern Australia and the other countries within Australia's RDMI. These regions have very few roads, almost no railway systems, only a limited number of major airfields, but many short, unprepared, grass or dirt airfields. The climate is tropical, and the countries to the north and parts of Northwest Australia are rugged and mountainous.

Clearly, some details of the Central American scenario that pertain to U.S. military forces used and the strategies and tactics employed may not be directly applicable to an Australian theater. However, the results of the airlifter analysis may provide some useful insights for tactical airlift in the Australian Defence Force.

Finally, one practical reason also determined the selection of Central America: execution time of the model. The baseline Central American scenario is the smallest scenario of the three and in batch mode takes five CPU minutes to run. By comparison, the next smallest scenario, Southwest Asia, requires 40 CPU minutes to run in batch mode. Given that the analysis would be carried out in the same manner for all scenarios, a shorter execution time will allow the runs to be made more expeditiously.

The Central American Scenario

The conflict in the notional Central American scenario is based upon a growing insurgency threat to El Salvador. This insurgency spills over into Honduras and cannot be contained by the local military. The

governments of both countries request military assistance from the U.S. in order to repel the insurgents (22:Sec 2-1 to 2-4).

The U.S. government responds by sending a Joint Task Force to Honduras. The task force is made up of three components: an Army, Air Force, and Naval component. The Army component consists of an airborne corps, whose main combat elements are a light infantry division and an airborne division. The Air Force component contains an air division from MAC, and a Tactical Air Wing. The Naval component is made up of a Naval Support Group and a Marine Amphibious Brigade (22:Sec 2-5).

The first ten days of the scenario are devoted to the strategic deployment of the ground and air forces into Honduras. Offensive operations begin on day 10 and last until day 30. Figure 2 shows a graphical summary of the operations carried out by the ground forces.

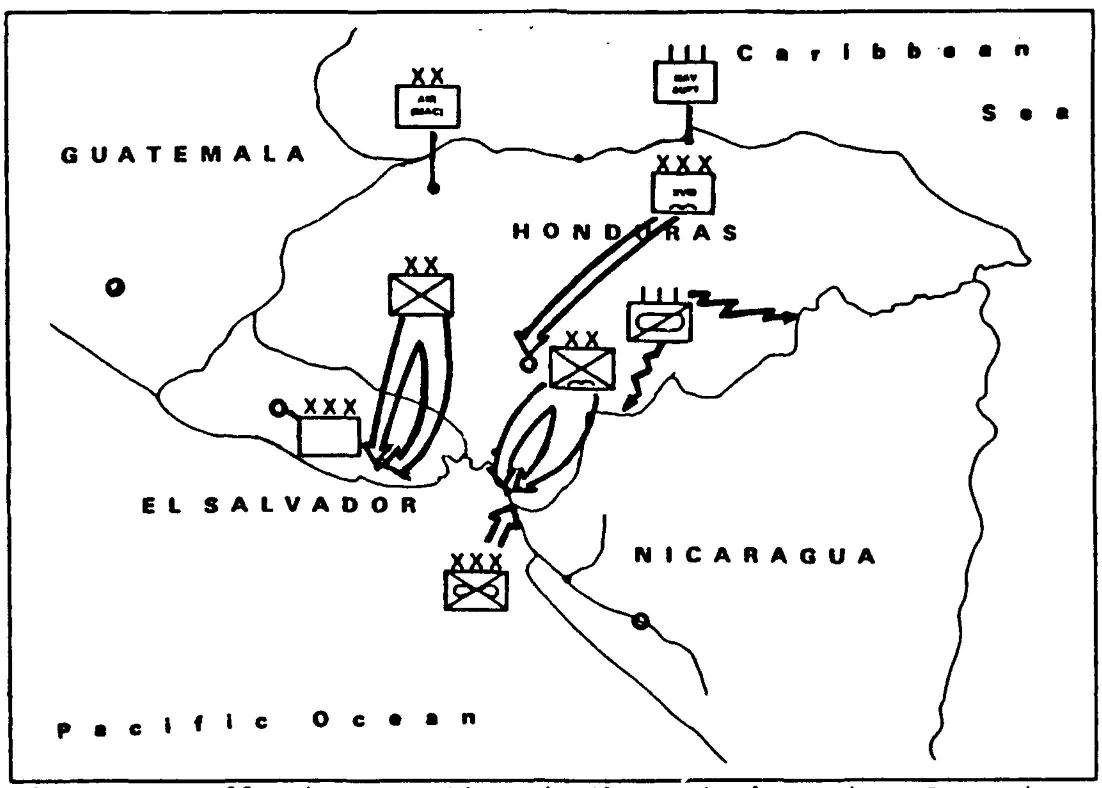


Figure 2. Offensive Operations in the Central American Scenario (22:Sec 2-10)

The locations of the various cities, airbases and E/D sites in the area of concern are shown in Figure 3, but the many small airfields that are available are not shown. Figure 3 also compares the position of the FLOT at day 10 when offensive operations began, to the position of the FLOT at day 21.

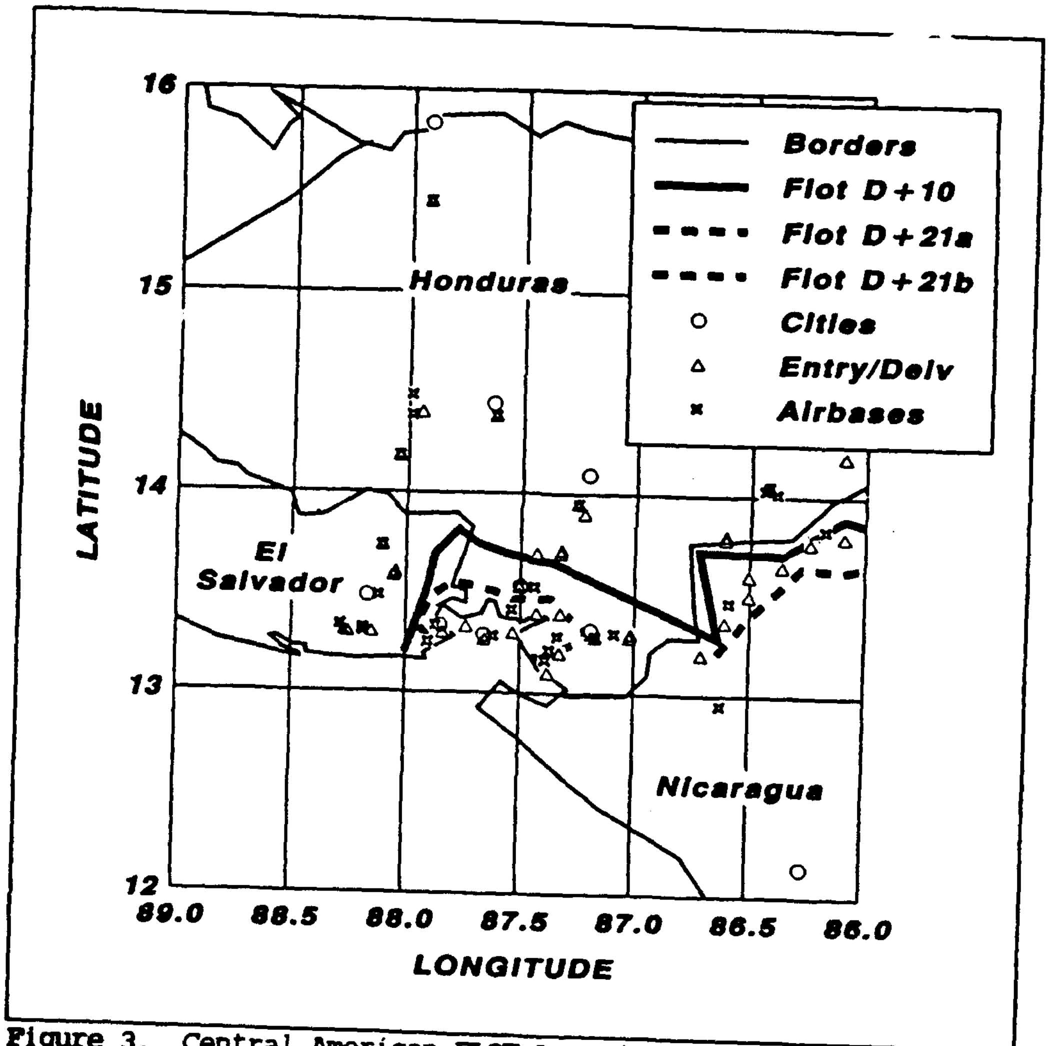


Figure 3. Central American FLOT Locations (22:Sec 3-2)

<u>The Tactical Airlift System</u>. In the baseline scenario, the tactical airlift system consisted of 16 C-130H and 2 C-17 aircraft. For the duration of the conflict, these aircraft are based out of a single

airbase in the north of Honduras. For the Central American theater, 16 representative airlift jobs were identified. The details of those jobs are presented in Appendix B and their occurrence is presented in Figure 4. These jobs were combined in Figures 5 and 6 to show the tonnage required to be airlifted by day and the cumulative tonnage required to be airlifted. The total tonnage required to be moved over the 30 day period is approximately 10,000 tons (22:Sec 5-2).

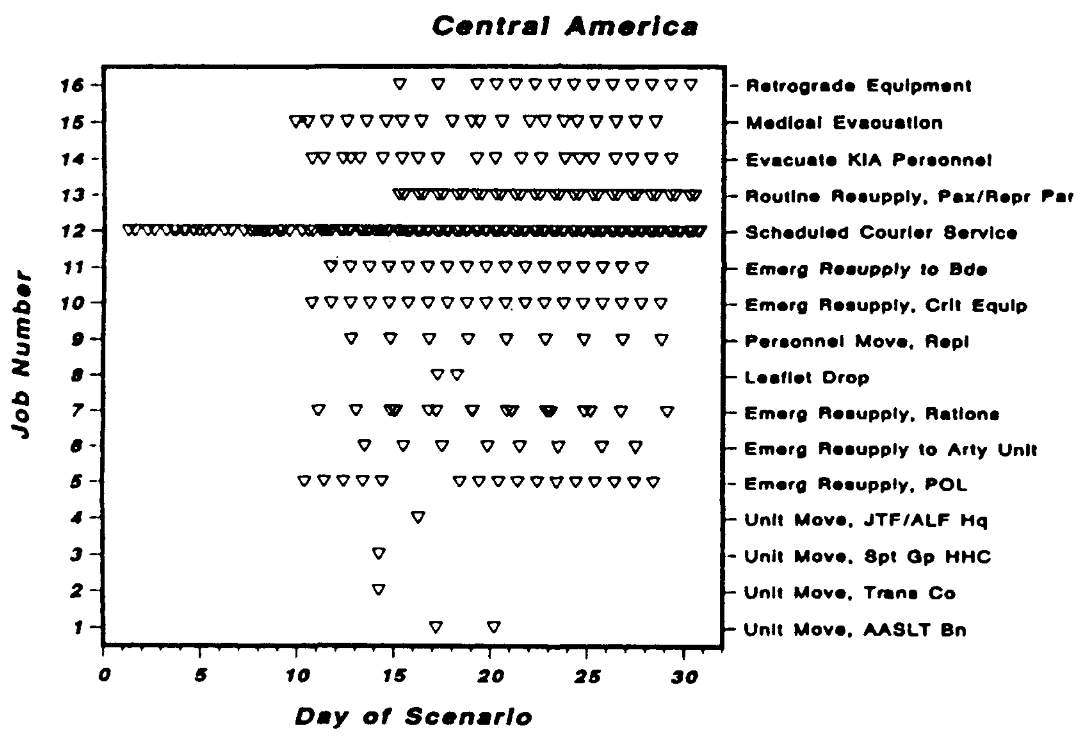


Figure 4. Central American Job Occurrences by Delivery Time (22:Sec 4-9)

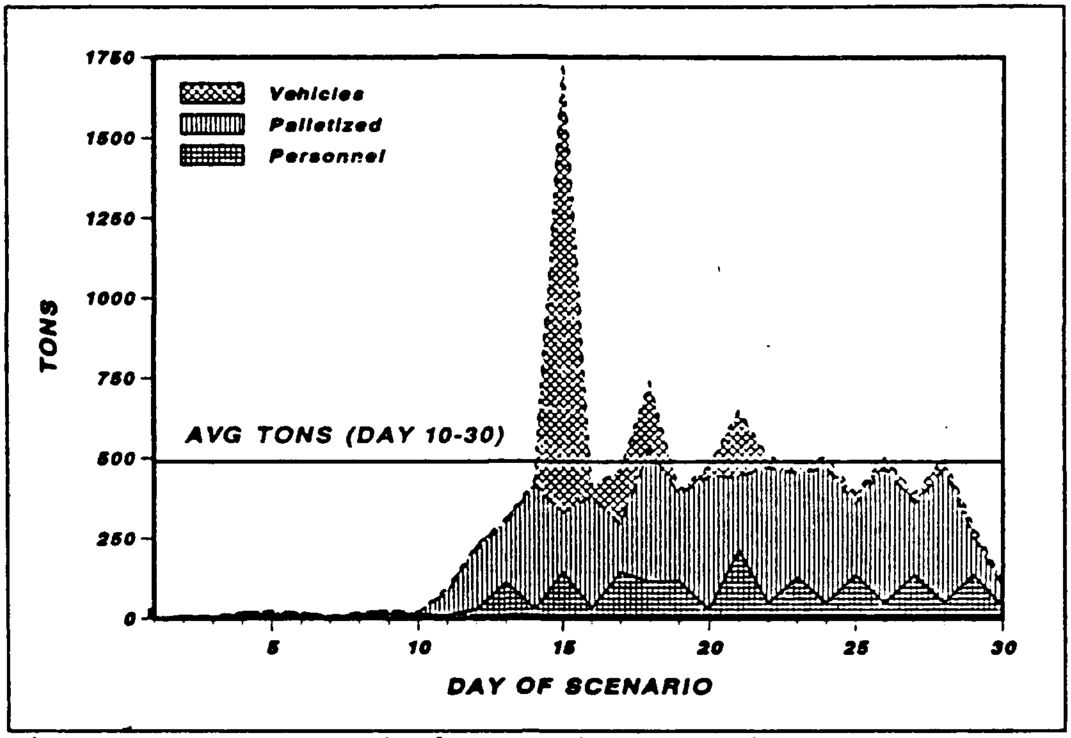


Figure 5. Tonnage Required By Day (22:Sec 5-2)

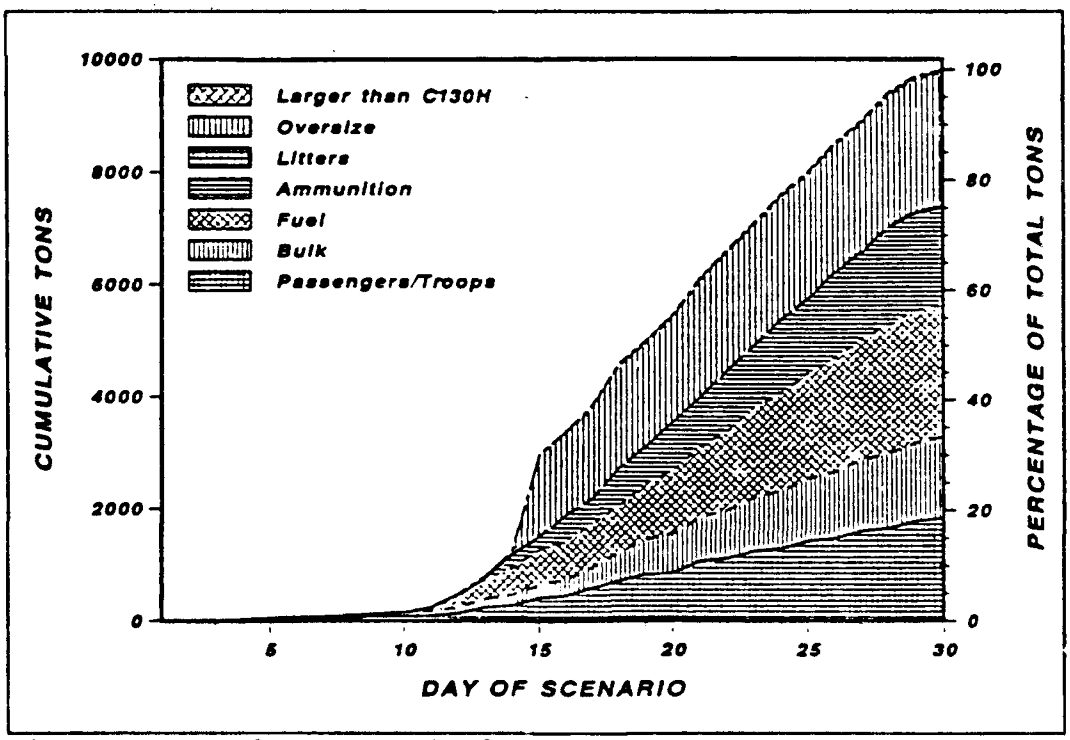


Figure 6. Cumulative Required Tonnage (22:5-2)

Summary

This chapter presented an overview of the Generalized Air Mobility Model (GAMM), the computer simulation model that will be used in this research. It identified the major elements of the simulation, and explained how these elements interact during the simulation.

A brief background was provided concerning the development of the scenarios used within GAMM, and the reasons why the Central American scenario was selected were outlined. Finally, a brief description of the Central American scenario was provided.

IV. Methodology

Introduction

This research will utilize GAMM as the basis for an experiment. The results from this experiment will be used to identify specific airlifter characteristics that produce the greatest improvement in tactical airlift capability. In this chapter, the following topics will be covered: the selection of an appropriate experimental design, the definition of experimental variables, and the selection of measures of effectiveness for the experiment. In addition, the methods used to analyze the experimental results and identify significant airlifter characteristics will be discussed.

Weakness of One-Variable-at-a-Time Strategy (4:510-513)

The deficiency analysis of the C-130H, carried out as part of the ATTMA project, was primarily intended to "identify specific airlifter-related problems which prevent the accomplishment of the required throughput on future battlefields" (24:Sec 3.4 1). This study found that no single deficiency significantly affected the C-130's airlift capability in Europe or Southwest Asia. In contrast, one deficiency that significantly affected the C-130's capability in Central America was the undercarriage's inability to operate on the many unprepared airfields in the region.

A previous study, carried out by ASD/XRM using response surface methodology techniques, attempted to screen the airlifter parameters

used within GAMM for significant effects. However, this study proved inconclusive and was never published (25).

While it was not intended as a screening analysis, the deficiency analysis was the only available study that used GAMM to identify significant tactical airlifter characteristics. For the majority of the runs, this was done by changing only one or two aircraft parameters at a time. The limitation of this method is highlighted in the example below, which is drawn from Chapter 15 of Statistics for Experimenters, by Box, Hunter and Hunter.

Suppose a chemist is trying to determine the maximum yield of certain chemical reaction that is dependent upon only two variables, the temperature of the reaction and the reaction time. The relationship of these two variables to the yield of the reaction is not known so the following experiment is set up.

For the first set of runs, the chemist fixes the temperature of the reaction at 225°C and varies the reaction time of the experiment. The results may look like the first graph of Figure 7. Having found a maximum yield at a reaction time of 130 minutes, the next set of runs locks the reaction time at 130 minutes and the reaction temperature is varied. The results may look like the second graph of Figure 7, showing a maximum yield at a temperature of 225°C. The chemist may then conclude that the maximum yield for this reaction occurs with a reaction temperature of 225°C and a reaction time of 130 minutes.

The chemist has assumed that the effect of each variable on the yield of the reaction is independent of the other variable. However,

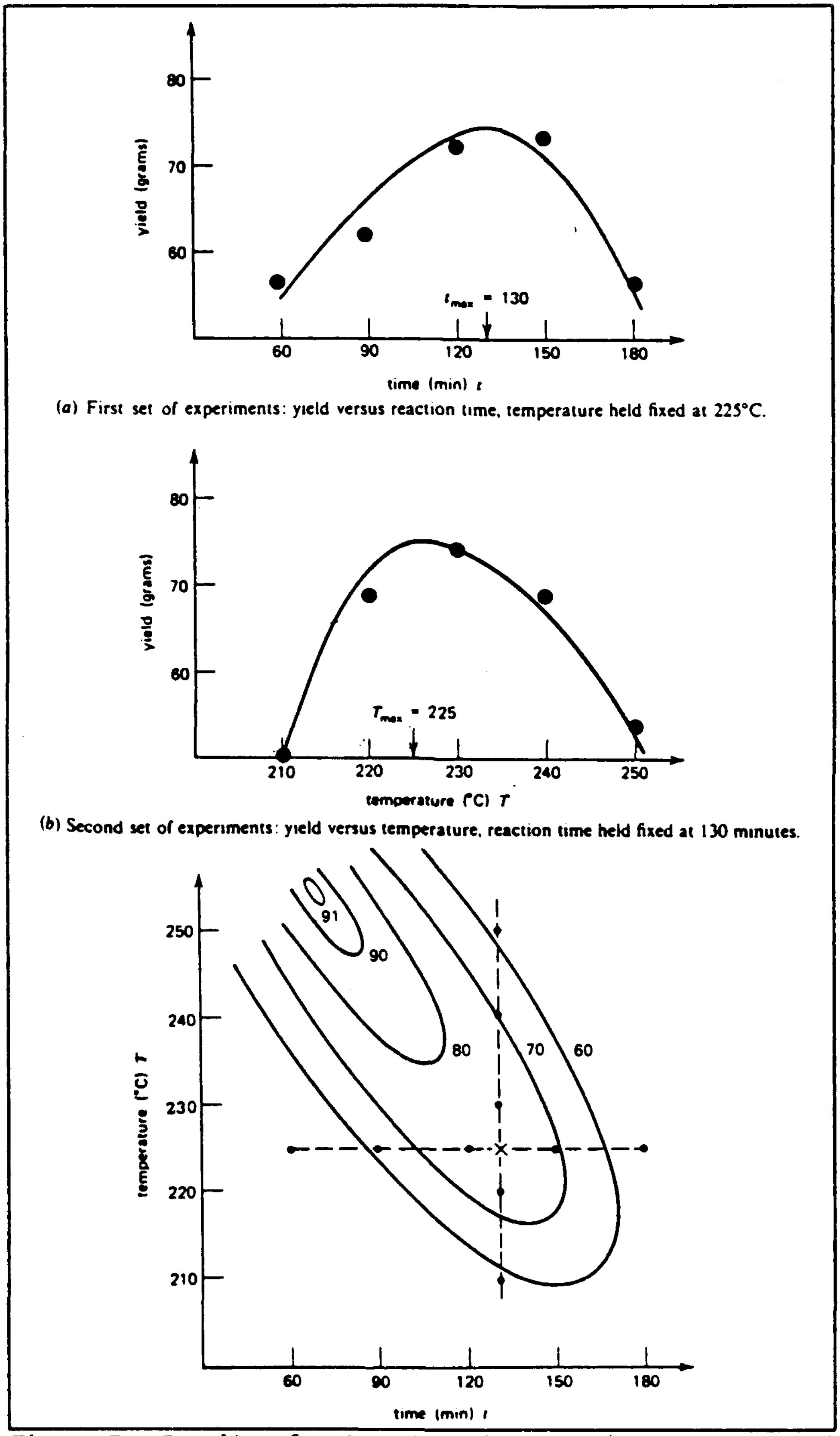


Figure 7. Results of a One-at-a-Time Experiment (4:511-521)

because the relationship of these variables on the yield is not known, this assumption may be incorrect.

The third graph of Figure 7 shows a contour diagram that could represent the "joint functional dependence of mean yield on time and temperature" for this reaction (4:512). It also shows the series of experiments that the chemist actually carried out using the one-at-a-time method. The graph clearly shows that the chemist was only able to determine a marginal optima for this reaction and that the values of the two variables at the true maximum yield for this reaction were significantly different from the values the chemist determined.

The limitation of the one-variable-at-a-time method is that it assumes the variables are independent. If the variables are not independent, this approach will lead to optimal settings for each variable, conditioned on the fixed levels of the other variables. This one-variable-at-a-time solution may be significantly different from the optimum solution. The deficiency analysis of the C-130H, by varying only one or two aircraft parameters at a time, assumed that the effect of these parameters on tactical airlift capability was independent. However, because the relationship between aircraft parameters and tactical airlift capability is not known, this assumption may not be correct.

Selection of an Experimental Design

In the situation where no theory is available to represent the relationship of variables to an output, an experimental design based on an empirical approach should be followed. One recommended empirical approach is the factorial design. Factorial designs allow each variable

to be assessed using a variety of different levels of all the other variables in the experiment (4:298-303). In addition, factorial designs "can also provide estimates of the 'effects' of the changes, which are infected as little as possible by experimental error" (4:302).

Factorial designs can be either full factorial, where all variables are compared at all levels, or fractional factorial, where a selected fraction of all the possible combinations is used. The individual experimenter chooses the number of levels at which each variable is tested and the type of factorial design that is to be used. For this analysis, a two level full factorial design was selected. That is, for each aircraft characteristic being assessed, two values were chosen. The two values represent the high and low levels of the two level factorial design. At each value, each characteristic is compared with every possible combination of the other characteristics. The strengths of this design are:

1. Fewer runs are required per variable studied because of greater precision. A one-variable-at-a-time method with k variables would generally require k times as many runs to achieve the same level of precision (4:312-313).
2. Major trends can be identified for further research.
3. Additional experiments can be easily added to the experiment to allow more thorough analysis.
4. The interpretation of the results "can proceed largely by common sense and elementary arithmetic" (4:306-307).

Factorial designs make the assumption that the output that is being modeled represents a smooth response surface without any

discontinuities, at least within the range of the characteristics selected.

> With any reasonable number of experimental runs, mapping a surface resembling a nest of stalagmites or the back of a porcupine would be impossible. Furthermore, for such a surface, sequential experimentation would be useless, since characteristics of the surface at one point would not be related to characteristics elsewhere. (4:300)

Given that most relationships do have some degree of continuity and smoothness, the experimenter must then select appropriate values for high and low levels of the variables being assessed. One shortcoming of the factorial design is that these values are selected without the experimenter knowing the shape of the response surface. The chosen values of the high and low levels of each variable must be wide enough apart to identify major trends in the response surface, such as the slope. However, these values cannot be so wide apart that the major features of the response surface, such as maxima, minima, or ridges, cannot be identified.

Another limitation of the two level factorial design is that it can only assess first order terms and their associated interaction terms. The two level factorial design essentially maps a plane, representing the first order and interaction terms, onto the response surface being assessed. The plane can identify major trends such as the slope of the surface, but it cannot provide information about the curvature of the surface, which is due to second and higher order terms. Additional experimental data points would be required to assess the curvature of the response surface within the region being examined by the two level factorial design (4:516).

Selection of Variables

For a two level full factorial design assessing *k* variables, the number of experiments required are 2^k. Testing all the aircraft parameters in GAMM using this design would require 2^{69} experiments. Since this was not practical, the number of parameters had to be rationalized. Two different methods were used to do this.

First, the scope of this analysis was reduced to only consider parameters related to airframes. All parameters related to reliability or vulnerability were set so that they would not affect the performance of the airlifter (see Appendix A). The Vulnerability Exponent was set to 1.00. This made the aircraft impervious to ground attack. All parameters related to Mean Time Between Failure were set to very large values so that reliability factors did not prevent aircraft from undertaking or completing a mission. In addition, all parameters in the scenario file that dealt with attrition were reset so that there was no attrition in the model. This included parameters for airbases, other airfields and drop zones, and also the transhipment links between E/D sites and the linked airfields.

By doing this, the analysis was assessing a system that was at its optimum performance. As other parameters were changed, the optimum performance of the tactical airlift system changed. The analysis could then be used to determine what combination of parameters resulted in the ultimate performance of the system.

A number of other parameters remained constant throughout and were not assessed. This included all parameters that concerned the stochastic nature of the model. Other parameters that remained the same

included Taxi, Takeoff and Landing time; Reserve Fuel; Payload Margin Next Flight; Loading and Unloading Factor for Rolling Stock; Mean Time to Repair; VTOL Max Useful Load; and Airfield Temperatures at Sea Level and at 5000 ft.

Having removed all these parameters from consideration, 43 parameters still remained. All the remaining parameters were considered to be significant to the experiment.

To reduce the number of variables in the experiment to more manageable numbers, the 43 parameters were then grouped into five functional sets. The five functional sets were: Field Performance (F), Cargo Cabin (C), Inflight Performance (I), Ground Flotation/Wheel Loading (G), and Servicing and Aircraft Loading/Unloading (S). The parameters contained in these sets are listed in Table 1.

The groupings were determined by combining parameters that were closely related in aircraft function or purpose. For example, cargo cabin size is related to the parameters for cargo bay width, height and length, and the size of the cabin directly affects the size of the aircraft (Aircraft Spot Factor). Generally, as aircraft increase in size, all cabin dimensions will increase and the aircraft's Maximum Cabin Payload will also tend to increase. Similarly, the Time to Unload, Service, and Load the aircraft directly affects aircraft turnaround times.

However, grouping the parameters confounds any analysis concerning individual parameters, because the effect of any single parameter would be combined with the effects of the other parameters within any one set. This limitation was accepted because the primary purpose of this

Table 1: GAMM Airlifter Functional Parameter Sets

Field Performance (F):
for sea level and at 5000 ft,
for hot and cold conditions

CTOL TO AT MAX USEFUL LOAD (FT)
CTOL LD AT MAX USEFUL LOAD (FT)
CTOL TO AT MID USEFUL LOAD (FT)
CTOL LD AT MID USEFUL LOAD (FT)
CTOL TO AT ZERO USEFUL LOAD (FT)
CTOL LD AT ZERO USEFUL LOAD (FT)

Cargo Cabin (C)

CARGO BAY WIDTH (INCH)
CARGO BAY HEIGHT (INCH)
CARGO BAY LENGTH (INCH)
CARGO BAY DOOR WIDTH (INCH)
CARGO BAY DOOR HEIGHT (INCH)
CTOL MAX USEFUL LOAD (LBS)
CTOL MID USEFUL LOAD (LBS)
MAXIMUM CABIN PAYLOAD (LBS)
AIRCRAFT SPOT FACTOR (NO)
CARGO THRESHOLD FOR RELOCATION (LBS)

Inflight Performance (I)

MAXIMUM FERRY FUEL (LBS)
CRUISE FUEL (LBS/HR)
CRUISE SPEED (KNOTS)
TAKEOFF/LANDING FUEL BIAS (LBS)

Ground Flotation/Wheel Loading (G)

LCN - MAX USEFUL LOAD (NO)
LCN - AT ZERO USEFUL LOAD (NO)

Servicing and Aircraft Loading/Unloading (S)

MEAN TIME TO SERVICE (HRS)
MEAN TIME TO LOAD (HRS)
MEAN TIME TO UNLOAD (HRS)

experiment was to screen the chosen variables to determine which were significant. If significant variables were found, the next step in the analysis might be to carry out a more detailed analysis of the individual parameters that comprised the significant sets. The parameters in the sets that were not significant could be disregarded with some level of confidence.

Defining Measures of Effectiveness

Before defining the value of the variables that will be used in the experiment, it is necessary to define the measures that will be used to determine the effectiveness of the tactical airlift system in GAMM. The deficiency analysis used two primary measures of effectiveness: Tons Delivered On Time, and Total Tons Delivered. For this experiment, however, because only one scenario is being used, the actual amount of cargo delivered is not as important as knowing what proportion of the total available cargo arrived on time and what proportion was actually delivered. Thus the primary measures of effectiveness will be Ratio on Time and Ratio Delivered.

In addition, four secondary measures of effectiveness were selected. These secondary measures were intended to assess how hard the tactical airlift system was being worked in order to achieve a given level of effectiveness. The four secondary measures were: Total Flight Hours, Total Sorties, Productive Flight Hours, and Productive Sorties. These four measures would also provide an indication of the efficiency of the tactical airlift system.

Specification of Variables

For the two level factorial experiment, high and low levels of the variables were required. To achieve this, the individual parameters within the variables were set to high and low levels. In selecting the values for these parameters, the following points were considered:

1. For the factorial design, the values had to be sufficiently far apart to ensure identification of a trend in the response surface.
2. The selected values could not be so far apart that they fail to identify significant features of the response surface.
3. Values should be selected around the C-130 baseline so that any significant findings can be directly related to the C-130 deficiency analysis previously carried out, and may also be directly applicable to the aircraft that becomes the C-130 replacement.

Suitable values were determined by the following procedure. The baseline C-130H parameters were multiplied by 2/3 to produce an aircraft that was two thirds the size of a C-130. The values for the cabin dimensions were then modified slightly to allow the cabin to hold three ammunition (AMMO) pallets (a single AMMO pallet has a base of 104 x 84 inches and in GAMM is 96 inches high). Similarly, the baseline C-130H parameters were multiplied by 4/3 to produce an aircraft that was four thirds the size of a C-130. Again, the cabin dimensions were modified slightly to enable the cabin to carry 7 AMMO pallets. For the majority of the parameters, the smaller values were half the larger values.

However, to define the high and low levels of each variable, the primary measure of Ratio On Time needed to be considered. Variables

were defined as high level if they were expected to increase the Ratio On Time value. Otherwise, they were defined as low level. Therefore, high and low levels do not always correspond to high and low values of the parameters. For Field Performance, the highest value of Ratio On Time is expected when aircraft can make use of shorter airfields. The high level of this variable corresponds to the smaller values of takeoff and landing distances. For Cargo Cabin and Inflight Performance, the high levels correspond to the larger parameter values. For the Ground Flotation/Wheel Loading and Servicing/Loading variables, increased throughput is expected when the values of the parameters are smaller. The high and low levels of the variables are defined in Table 2.

One other important operational aspect that might influence the efficacy of the tactical airlift system was the number of available aircraft. In the baseline analysis and the deficiency analysis previously mentioned, two aircraft types were used in each scenario: the C-17, and the C-130 or C-130 variants. However, for this analysis, the C-17 was not used because having more than one aircraft type in the scenario would make the interpretation of the results more difficult. For the single aircraft type used in the scenario, the number of aircraft was varied from a low level to a high level. The high level was set at 32 aircraft, and the low level was 16 aircraft.

These six variables, Aircraft Numbers (A), Field Performance (F), Cargo Cabin (C), Inflight Performance (I), Ground Flotation/Wheel Loading (G), and Servicing and Aircraft Loading/Unloading (S), form the basis of the experiment. Table 3 shows the design matrix of this 2^6 two level full factorial design. For convention, the high level of the

Table 2. Definition of Variables - Two Level Factorial Design

Field Performance (F)	- SEA LEVEL -		- 5000 FEET -	
	HOT	COLD	HOT	COLD
High Level (+)	103 F	59 F	84 F	41 F
CTOL TO AT MAX USEFUL LOAD (FT)	2387	1787	2713	2293
CTOL LD AT MAX USEFUL LOAD (FT)	1520	1433	1713	1620
CTOL TO AT MID USEFUL LOAD (FT)	1320	1080	1560	1340
CTOL LD AT MID USEFUL LOAD (FT)	1260	1200	1400	1333
CTOL TO AT ZERO USEFUL LOAD (FT)	720	633	827	740
CTOL LD AT ZERO USEFUL LOAD (FT)	1000	947	1093	1020
Low Level (-)				
CTOL TO AT MAX USEFUL LOAD (FT)	4773	3573	5427	4587
CTOL LD AT MAX USEFUL LOAD (FT)	3040	2867	3427	3240
CTOL TO AT MID USEFUL LOAD (FT)	2640	2160	3120	2680
CTOL LD AT MID USEFUL LOAD (FT)	2520	2400	2800	2667
CTOL TO AT ZERO USEFUL LOAD (FT)	1440	1267	1653	1480
CTOL LD AT ZERO USEFUL LOAD (FT)	2000	1893	2187	2040

Cargo Cabin (C)	High Level (+)	Low Level (-)
CARGO BAY WIDTH (INCH)	131	95
CARGO BAY HEIGHT (INCH)	126	97
CARGO BAY LENGTH (INCH)	656	350
CARGO BAY DOOR WIDTH (INCH)	140	100
CARGO BAY DOOR HEIGHT (INCH)	130	100
CTOL MAX USEFUL LOAD (LBS)	96000	48000
CTOL MID USEFUL LOAD (LBS)	49332	24667
MAXIMUM CABIN PAYLOAD (LBS)	67733	33867
AIRCRAFT SPOT FACTOR (NO)	1.4	0.7
CARGO THRESHOLD FOR RELOCATION	20000	10000

Inflight Performance (I)	High Level (+)	Low Level (-)
MAXIMUM FERRY FUEL (LBS)	77960	39980
CRUISE FUEL (LBS/HR)	7067	3533
CRUISE SPEED (KNOTS)	360	180
TAKEOFF/LANDING FUEL BIAS	2000	1000

Ground Flotation/Wheel Loading (G)

	High Level (+)	Low Level (-)
LCN - MAX USEFUL LOAD (NO)	26	52
LCN - AT ZERO USEFUL LOAD (NO)	12	24

Servicing and Aircraft Loading/Unloading (S)

	High Level (+)	Low Level (-)
MEAN TIME TO SERVICE (HRS)	0.35	0.7
MEAN TIME TO LOAD (HRS)	0.6	1.4
MEAN TIME TO UNLOAD (HRS)	0.2	0.4

Aircraft Numbers (A)	32	16

Table 3. 2^6 Two Level Full Factorial Design Matrix

Test Condition Number	Design Matrix Variables						Identification	Test Condition Number	Design Matrix Variables						Identification
	A	F	C	I	G	S			A	F	C	I	G	S	
1	-	-	-	-	-	-		33	-	-	-	-	-	+	S
2	+	-	-	-	-	-	A	34	+	-	-	-	-	+	AS
3	-	+	-	-	-	-	F	35	-	+	-	-	-	+	FS
4	+	+	-	-	-	-	AF	36	+	+	-	-	-	+	AFS
5	-	-	+	-	-	-	C	37	-	-	+	-	-	+	CS
6	+	-	+	-	-	-	AC	38	+	-	+	-	-	+	ACS
7	-	+	+	-	-	-	FC	39	-	+	+	-	-	+	FCS
8	+	+	+	-	-	-	AFC	40	+	+	+	-	-	+	AFCS
9	-	-	-	+	-	-	I	41	-	-	-	+	-	+	IS
10	+	-	-	+	-	-	AI	42	+	-	-	+	-	+	AIS
11	-	+	-	+	-	-	FI	43	-	+	-	+	-	+	FIS
12	+	+	-	+	-	-	AFI	44	+	+	-	+	-	+	AFIS
13	-	-	+	+	-	-	CI	45	-	-	+	+	-	+	CIS
14	+	-	+	+	-	-	ACI	46	+	-	+	+	-	+	ACIS
15	-	+	+	+	-	-	FCI	47	-	+	+	+	-	+	FCIS
16	+	+	+	+	-	-	AFCI	48	+	+	+	+	-	+	AFCIS
17	-	-	-	-	+	-	G	49	-	-	-	-	+	+	GS
18	+	-	-	-	+	-	AG	50	+	-	-	-	+	+	AGS
19	-	+	-	-	+	-	FG	51	-	+	-	-	+	+	FGS
20	+	+	-	-	+	-	AFG	52	+	+	-	-	+	+	AFGS
21	-	-	+	-	+	-	CG	53	-	-	+	-	+	+	CGS
22	+	-	+	-	+	-	ACG	54	+	-	+	-	+	+	ACGS
23	-	+	+	-	+	-	FCG	55	-	+	+	-	+	+	FCGS
24	+	+	+	-	+	-	AFCG	56	+	+	+	-	+	+	AFCGS
25	-	-	-	+	+	-	IG	57	-	-	-	+	+	+	IGS
26	+	-	-	+	+	-	AIG	58	+	-	-	+	+	+	AIGS
27	-	+	-	+	+	-	FIG	59	-	+	-	+	+	+	FIGS
28	+	+	-	+	+	-	AFIG	60	+	+	-	+	+	+	AFIGS
29	-	-	+	+	+	-	CIG	61	-	-	+	+	+	+	CIGS
30	+	-	+	+	+	-	ACIG	62	+	-	+	+	+	+	ACIGS
31	-	+	+	+	+	-	FCIG	63	-	+	+	+	+	+	FCIGS
32	+	+	+	+	+	-	AFCIG	64	+	+	+	+	+	[illegible]	AFCIGS

variables is coded by a plus sign and the low level by a minus sign (4:308).

Standard GAMM Initializing Parameters

When initializing a scenario using GAMM, the user is presented with a series of questions that he must answer to run the program. Some of the questions relate to the airlift job and scenario files that are about to be used in GAMM. A large proportion simply require the user to respond Yes or No to the questions.

In addition to these, a number of the questions ask for values to be specified for parameters that are used within the whole model. Some of the parameters that can be specified here include the Priority Scheduling Factor, the user determined method for aircraft loading, and the length of the crew duty day for aircrew. Variation in these parameters can cause a dramatic change in the results of the simulation without changing any other aspect of the scenario.

An example of the questions presented in the initialization of GAMM is contained in Appendix C. The questions and the responses in Appendix C are based on the use of an existing scenario and jobs file, multiple repetitions of the scenario, and the model being run in batch mode rather than in interactive mode. The order and number of questions will vary if the user responds differently to the questions, but the questions that define the parameters initializing GAMM will always be asked. A more extensive listing of these initial questions can be found in the GAMM User's Manual (10:Sec 3-1 to 3-249).

To standardize the experiments in GAMM, the initializing parameters were set at the same values used in the baseline analysis for

all the simulation runs. These values were also used for the majority of the runs carried out in the deficiency analysis. By using the same initializing parameter values, the results of this analysis could be directly compared to the results of the previous studies. The parameter values can be found in Appendix C.

Stochastic Modeling

> A discrete event simulation is in fact a statistical experiment. The output variables are estimates that contain random error, and therefore a proper statistical analysis is required. Such a philosophy is in contrast to the analyst who makes a single run and draws an inference from that single data point. (3:15)

The stochastic nature of a simulation is the result of two factors: a random number generator, and parameters within the model that are described by a statistical distribution. Within GAMM, a number of parameters are defined with a mean value and a standard deviation. These parameters are shown in Appendix A. The random number generator within GAMM uses these values to generate a random value within the possible distribution of values, for any single event. For modeling purposes, this technique is used to model the range of variation that occurs in the real world.

A user defined random number seed determines the sequence of random numbers produced by the random number generator. Therefore, runs of a simulation using the same random number seed will always result in the same output. To achieve the real world variation in simulation output, genuine replications are required. That is, the random number streams used for multiple replications must be different for each replication.

As mentioned earlier, a number of parameters were held constant for all experimental runs. This included all standard deviation parameters (see Appendix A). However, for this experiment, the parameters in the input files that represent standard deviations were set to very small numbers. Since the algorithms for calculating parameter values within GAMM would not accept standard deviations of zero, values of Ø.ØØ1 or Ø.Ø1 were used. Such an approach rendered the model more deterministic. An additional advantage of restricting the variation in the simulation was a reduction in the minimum number of replications needed for statistical analysis.

To ensure that each run was randomized as much as possible, a different random number seed was used for each batch of runs. Because different random numbers are being used for calculations within the model, the results of different runs should be completely independent from one another.

Determining the Required Number of Replications (3:421-429)

It is not possible to estimate the accuracy of the output of a simulation from a single run. Multiple replications under identical conditions are required to establish a confidence interval about a statistic. However, carrying out a large number of replications is time consuming. A method is needed to determine the minimum number of replications required to achieve a specific level of accuracy for the output. One method is outlined below.

A number of simulation runs are carried out, each repeated a total of R times, with each run using a different random number stream (3:421). The accuracy of the output measure can be defined by the half-

length of a 100(1-α)% confidence interval for a mean $\boldsymbol{\theta}$, based on the t distribution, as follows:

$$h.l. = t_{\alpha/2,R-1}\hat{\sigma}(\hat{\theta}) \qquad (1)$$

where

$$\hat{\sigma}(\hat{\theta}) = \frac{S}{\sqrt{R}}$$

and

S = the sample standard deviation

R = the number of replications

From an initial sample of R_0 independent replications, an estimate, S_0^2, of the population variance, σ^2 can be obtained. For a given level of accuracy, ε, to meet the half-length criteria, a sample size R must be chosen such that $R \geq R_0$ and

$$h.l. = \frac{t_{\alpha/2,r-1}S_0}{\sqrt{R}} \leq \varepsilon \qquad (2)$$

Solving the inequality for R gives:

$$R \geq \left(\frac{t_{\alpha/2,R-1}S_0}{\varepsilon}\right)^2 \qquad (3)$$

From a series of independent single simulation runs, each using different random number seeds, the values of the six output measures that are going to be used in the analysis are recorded. A sample standard deviation can be calculated by selecting R_0 number of values for each of the output measures. By choosing appropriate values for the

probability α and the accuracy ε, the right hand side of Equation 3 can be determined. If the value calculated for the right hand side of Equation 3 is greater than R_0, then the sample needs to be increased. Additional values are added to the sample and the calculations are repeated. When the right hand side of the equation is calculated to be less than R_0, the value of R_0 represents the minimum number of replications required to achieve the specified accuracy with the specified probability.

Because six output measures are being considered in this analysis, the value selected as the minimum number of replications must result in all six measures achieving the specified accuracy and probability.

Modification of Scenario Files

One of the assumptions of the factorial design is that the functions being modeled are smooth and continuous. If the functions are not smooth and continuous, a factorial experiment would not be able to determine the true characteristics of the surface being mapped.

This assumption is significant in the Central American scenario because of the importance of one set of parameters in the model: the aircraft's Load Classification Numbers (LCN). LCN values are used to determine the maximum cargo that can be carried by an aircraft to a destination airfield.

For each aircraft type, two parameters are required: LCN at empty weight and LCN at maximum payload. Also, each airfield has an LCN value which determines the largest and heaviest aircraft that can safely operate into that field. If the destination airfield's LCN value is small, less cargo can be flown in per aircraft. However, the more

critical situation occurs when the LCN value of the destination airfield is so small that the aircraft cannot operate into that airfield at any weight.

Of the 33 airfields in the Central American scenario, 13 airfields cannot be used by any airlifter in the experiment because their LCN values are less than 12. This value is the LCN at aircraft empty weight for the high level of the Ground Flotation variable, that is, the variable that allows the aircraft to land on the softest airfields. Another 11 airfields have an LCN value that is less than 24, which is the LCN value at aircraft empty weight for the low level of the Ground Flotation variable.

Only 9 airfields remain. Given that one of the airfields is used as the home base of the aircraft, only 8 airfields are available as in-theater destinations that allow operations at both levels of the Ground Flotation variable. The impact of this on the likely performance of the airlift system can be determined by examining both the scenario file and the jobs file. Airlift jobs that originate or are destined for E/D sites that are not linked to one of the nine major airfields would be blocked at the low level of the Ground Flotation variable, resulting in a discontinuity. 14 such sites were identified in the scenario file.

To prevent any discontinuity, the scenario file needed to be modified so that these 14 locations were linked to the 9 major airfields. To do this, the location of the 9 airfields were mapped onto graph paper, along with the network that represented the links of the 14 locations. This identified the nearest major airfield to each of these locations. The scenario file was then used to identify E/D sites that

linked the major airfields to the airfields that were linked to the 14 sites. For all 14 sites, it was possible to identify a path, consisting of existing links, that linked each of the 14 sites to at least one major airfield.

The scenario file used in the experiment was modified to include these new paths as additional links. The transhipment time for each of the new links was the sum of the transhipment times of each of the existing links along the new path.

Analysis of the Main Effects of a Two Level Factorial Design (4:309-313)

Two methods for analyzing the results of a two level factorial experiment are outlined by Box: a difference between two averages to determine the mean value for each effect, and Yate's Algorithm. The first method will be discussed initially.

Each variable in the experiment was tested at two levels, a high level and a low level. In the design matrix, the high levels of each variable were identified by a '+' sign and the low levels by a '-' sign. Using the difference between two averages method, the average effect of a variable was calculated by subtracting the average value of all the experimental results for which the particular variable was '-' from the average value of all the experimental results for which the variable was '+'. The result is a value that represents the main effect of that variable on the output measure.

While a detailed explanation of the analysis of results will be discussed in following sections, in simple terms, the further away the value of the effect is from zero, the more significant is the effect of that variable.

Analysis of the Interaction Effects of a Two Level Factorial Design (4:313)

Interactions between variables occur when the effect of one variable is not completely independent of other variables. That is, when the effect of one variable on the outcome of the experiment is a function of the level of the other variables. Factorial designs are able to estimate the effect of these interactions.

For this 2^6 experiment, interactions can occur as a result of two, three, four, five, or six variables interacting. The number of possible combinations of n factor interactions in this experiment is given by the combination formula:

$$\binom{6}{n} = \frac{6!}{n!\,(6-n)!} \tag{4}$$

where n = the number of interacting variables

The level for each interaction term can be determined by multiplying the signs of the individual interacting variables for each experiment. For example, for a two factor interaction where both variables are at a low level, that is, '-' and '-', the two factor interaction term is at the '+' or high level. The columns for all the interaction terms in the 2^6 factorial experiment are contained in Appendix D.

The calculation of the average effect of an interaction term is the same as for the main effects except that the column of '+' and '-' signs from design matrix corresponds to the appropriate interaction term rather than a main effect. The average effect of an interaction term is

found by subtracting the average of all the results where the interaction level was low (-) from the average of all the results where the interactive term was high (+).

Again, an interaction term is significant when the effect is significantly different from zero.

<u>Yate's Algorithm</u> (4:323-324)

Yate's algorithm is an alternative method for calculating the effects of a two level factorial design. Before Yate's algorithm can be applied, the results of the experiment need to be arranged in a standard order. The standard order for a 2^k factorial design is where:

> the first column of the design matrix consists of successive minus and plus signs, the second column of successive pairs of minus and plus signs, the third column of four minus signs followed by four plus signs, and so forth. In general, the *k*th column consists of 2^{k-1} minus signs followed by 2^{k-1} plus signs. (4:323)

The design matrix in Table 3 is laid out in this standard order. Results from the experiments are aligned in the order given by this matrix. An example of the calculations involved in the Yate's algorithm is given in Figure 8. This example, taken from Box, Hunter and Hunter, is a 2^3 factorial experiment, with the three variables identified by T, C, and K.

The values for the top half of the first column of Yate's algorithm are obtained by adding successive pairs of results together. For the bottom half of this column, values are calculated by subtracting successive pairs of results, with the top number of each pair being subtracted from the bottom number of that pair.

Each successive column of the algorithm is calculated in the same manner, using the values of the preceding column. For a 2^k factorial

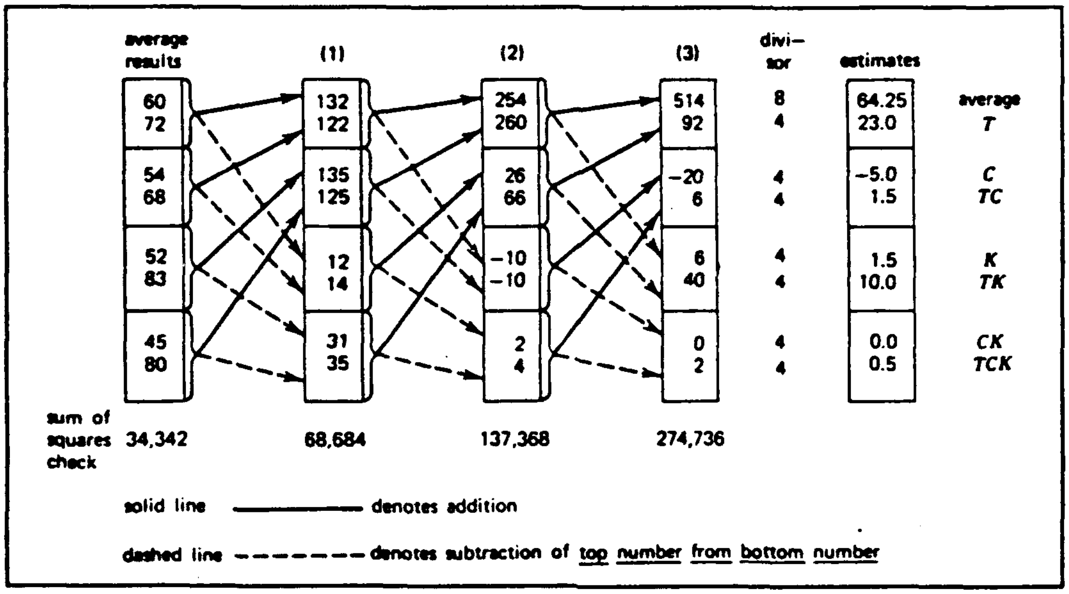


Figure 8. Yate's Algorithm - 2^3 Factorial Experiment (4:342)

design, k columns need to be generated in this manner. The column of estimates is calculated using the kth column. The topmost number is divided by 2^k to produce an estimate of the average value of the output measure across all the experimental runs. The remaining numbers are divided by 2^{k-1} to produce estimates for the effect of the terms represented by the plus signs on the same row of the design matrix. These terms are identified in the right hand column of the Yate's algorithm. The terms for this experiment are shown in Table 3 alongside their corresponding row of the design matrix.

Analysis of the Results of a Two Level Factorial Experiment

To determine which values are significant, a standard error needs to be calculated. However, because each output measure only produces a single value for each run, no direct calculation of σ^2 can be made. An estimate of the standard error can be made using the results from higher

order interactions, if certain assumptions can be made. Specifically, if the response function is smooth and continuous, as was assumed in the selection of the factorial design for this analysis, then higher order interactions should be small. The higher order interactions would then "measure differences arising principally from experimental error" (4:327).

The variance of the results can then be calculated as the mean of the sum of squares of the higher order interactions, and the standard error is the square root of this value. For this experiment, all three, four, five, and six factor interaction terms will be assumed to be negligible, and the results from all these terms will be used to determine an initial estimate of the standard error for each output measure (4:327-328). Once the standard error has been calculated, the significant terms can be identified.

If a term is not significant, the value of the output will remain the same irrespective of the level of that particular term. Because the estimate of the effect of a term is the difference between the average effect of the term at a high level and the average effect of the term at a low level, for terms that are not significant, this estimate will be close to zero. If all terms are negligible, the estimates would all represent experimental error, and for a large enough sample of results, would be normally distributed about zero. Therefore, 99.74% of all the estimates would lie within three standard deviations of zero.

An estimate which lies outside three standard deviations from zero is most likely to be a significant term. For the analysis of results for this experiment, all terms with estimates that have an absolute

value greater than three standard deviations from zero will be considered significant.

Development of a Regression Model

All the significant terms identified by the previous method will be used to develop an initial regression model that represents the underlying response function. This regression model takes the form:

$$\hat{y} = \bar{y} + \left(\frac{\beta_1}{2}\right)x_1 + \left(\frac{\beta_2}{2}\right)x_2 + \ldots + \left(\frac{\beta_n}{2}\right)x_n \qquad (5)$$

where

$\hat{y}$ = the estimate of the output

$\bar{y}$ = the estimate of the average output across all experimental runs

β_n = the estimate of the effect of the nth term calculated by Yate's algorithm

x_n = the nth term

In the factorial design, the actual estimate of the effect, β_i, measures the change in the estimated result when the variable, x_i, changes from -1 to +1, which is a change of two units. The coefficients of each significant term in the regression equation represent the change in the estimated result when the variable, x_i, is changed by one unit. Therefore, the coefficients used in the regression equation are half the estimated effects calculated using Yate's algorithm (4:514).

The regression equation can be used to calculate estimates of the output for each experimental run by substituting +1 or -1 for variables,

based upon the level of each variable in each row of the design matrix. These estimates of the output can then be used to determine the closeness of fit of the estimated regression function to the actual response function. The value of the residual is given by:

$$Y_i-\hat{Y}_i = Y_i-\overline{Y}-(\hat{Y}_i-\overline{Y}) \tag{6}$$

where, for the ith observation,

Y_i = *the actual result*

$\hat{Y}_i$ = *the estimated result*

$\overline{Y}$ = *the overall mean*

$Y_i-\hat{Y}_i$ = *the residual*

Equation 6 states that the residual is the difference between the deviation of the actual results from the overall mean and the deviation of the estimated results from the overall mean. Equation 6 can be rewritten as follows:

$$(Y_i-\overline{Y}) = (\hat{Y}_i-\overline{Y})+(Y_i-\hat{Y}_i) \tag{7}$$

By squaring both sides of Equation 7 and simplifying the resulting expression, the following equation is obtained (8:17-18):

$$\Sigma(Y_i-\overline{Y})^2 = \Sigma(\hat{Y}_i-\overline{Y})^2+\Sigma(Y_i-\hat{Y}_i)^2 \tag{8}$$

In simpler terms, Equation 8 states that the sum of the squares about the mean is equal to the sum of the squares due to the regression plus the sum of the squares of the residuals.

Equation 8 will be used to construct an Analysis Of Variance (ANOVA) table which will provide information about the accuracy of fit of the regression equation. However, in addition to using the ANOVA table, an analysis of the residuals will need to be carried out. Two different methods will be used to analyze the residuals: a plot of the residuals against the predicted responses and a normal probability plot of residuals.

The plot of residuals against the predicted responses will allow an assessment of nonlinearity and of non-constant variance. If the plot of the residuals indicates that there may be nonlinearity, this would indicate that higher order terms are required in the regression equation. (As has been mentioned previously, a two level factorial experiment cannot assess curvature.) Non-constant variance may indicate that some transformation is required to produce a better fitting regression equation. The normal probability plot of the residuals is used to check that the residuals are normally distributed.

By combining the analysis of the ANOVA table with the analysis of the two plots of the residuals, an assessment as to the usefulness of the regression equation can be made. This procedure will be carried out for each of the six measures of effectiveness used in this experiment.

Development of a Parsimonious Model

In the development of the initial regression equations for each of the measures of effectiveness, all the statistically significant terms would be included. Even though higher order interactions were not expected to be significant, there may still be a large number of terms contained in the regression equations. However, while these terms may

be statistically significant by comparison to the higher order interactions, they may not significantly contribute to the regression model being developed. For the final analysis, a parsimonious model is required, that is, a model that uses the smallest possible number of terms but still provides an adequate representation of the function being modeled.

A parsimonious model will be developed for each of the output measures using a stepwise regression methodology. For each of the parsimonious models developed, an ANOVA table and the plots of the residuals will be used to assess the goodness of fit of the model.

Identification of Significant Aircraft Characteristics

The result of the analysis should be six parsimonious regression functions. The variables in these six regression functions represent the set of aircraft characteristics that are most significant to each of the measures of effectiveness.

However, the explanation of the significance of each variable depends upon the presence of that variable in any interaction terms. If a variable is not in an interaction term, then that particular aircraft characteristic directly affects the result of the given output measure, and so can be considered significant. If a variable is contained in an interaction term, irrespective of whether or not it also appears as a single term, that aircraft characteristic can only be explained in terms of the interaction of that characteristic with the other characteristics in that interaction term.

Summary

The experimental design chosen for this research was a two level full factorial design. Forty three aircraft parameters in GAMM were grouped into five experimental variables: Flight Performance, Cargo Cabin, Inflight Performance, Ground Flotation/Wheel Loading, and Servicing and Aircraft Loading/Unloading. An additional variable, Aircraft Numbers, was also included. The experimental design used for this research was therefore a 2^6 factorial design.

Six measures of effectiveness were selected. Ratio On Time and Ratio Delivered were the primary measures of the throughput of the tactical airlift system. Four secondary measures, Total Flight Hours, Total Sorties, Productive Flight Hours, and Productive Sorties, were selected to assess the efficiency of the tactical airlift system.

Two methods for analyzing the results were presented: the difference between two averages and Yate's algorithm. Both methods would identify terms that had a statistically significant effect upon the measure of effectiveness when the level of that term changed from high (+) to low (-). For each measure of effectiveness, all statistically significant terms would be used to develop an initial regression model. From this, parsimonious models could then be developed.

The parsimonious models would contain the smallest possible number of terms that still adequately represented the underlying response functions. The variables contained in the terms of the parsimonious models would represent the set of aircraft characteristics that had the most significant effect on the tactical airlift system.

V. Verification and Validation

Introduction

Before GAMM was used for this experiment, it was necessary to determine the extent to which the model had been verified and validated. Verification of a computer simulation is concerned with ensuring that the computer program is performing the way that it was intended to perform. "If the input parameters and the logical structure of the model are correctly represented in the code, verification has been completed" (3:14). Validation of a simulation is the process of determining that the simulation is "an accurate representation of the real system" (3:14). In simpler terms, "validation deals with building the right model, verification deals with building the model right" (21:559).

Verification of GAMM

Verification of a simulation model is the responsibility of the modeler who defines the model specification and the software engineers who program the model (21:567-568). It is an essential step during the development of a simulation model.

No documentation about the initial development and verification of GAMM was available. Also, because the author was a representative of a foreign military service, the source code for GAMM was not available for analysis. As a result, the extent of the initial verification effort for GAMM could not be determined.

However, a number of documents provided some insight about the

extent of verification of GAMM. The GAMM Programmer/Analyst's Manual provided extensive detail about the logic used within the model. In particular, Section 4 describes the most significant software events and routines, and supplemented these descriptions with flow charts that represented the way the actual coding of the event or routine had been carried out (9:Sec 4). Section Two of the GAMM User's Manual used a simple example of a tactical airlift scenario to step through the GAMM flight scheduling algorithm. The example used four airbases, seven E/D sites and ten aircraft to show the sequence of movement of 18 jobs through the tactical airlift system to their final destinations (10:Sec 2-16 to 2-30).

GAMM has evolved from a simplistic tactical airlift model to a more elaborate and more realistic model of a future tactical airlift system (16:1). The first version of GAMM to be developed was identified as Version 0.5. With each major change to the model a new version was released. The current version of GAMM is Version 3.5. In 1990, a System Concept Evaluation Baseline analysis was undertaken by the developers of GAMM, the General Research Corporation (GRC). The purpose of this study was to highlight "the enhancements to GAMM in evolving from GAMM 0.5 to GAMM 3.4" and to provide "comparative assessments to illustrate the ramifications of current algorithms" (16:1).

> GRC is to review results from similar runs made with each of the two versions of GAMM, to identify significant differences between the two sets of results, to determine and explain the cause of these differences, and to implement corrective action to resolve software problems. (16:1)

This baseline analysis and comparative assessment was used to verify the performance of Version 3.4. In addition, the baseline

analysis contains a list of all the modifications made to GAMM since the original version (16:3-6).

Version 3.5 differed from Version 3.4 in that one parameter was added to the model. The new parameter, the logistical pipeline delay, represented the time it would take a Maintenance Repair Team to reach an aircraft that had broken down (25). This parameter was significant where an aircraft had broken down away from a major airbase, and had the effect of increasing the total time required to repair the aircraft. In all other aspects, Version 3.5 is identical to Version 3.4.

Validation of GAMM (25; 26)

No formal validation of GAMM has been carried out (25). However, in 1989, ASD/XRM tasked GRC to carry out a specific series of tests of GAMM. The purpose of these tests was to both validate and verify GAMM, Version 3.Ø. Eighteen specific categories within GAMM were tested. These categories included:

1. Airbase preferences.
2. Airlifter scheduling and relocation. This category included the selection of cargo for airlift, calculation of reduced payloads due to runway conditions, and movement item priority selections.
3. Airdrops.
4. Fuel/payload calculations.
5. Crew day expiration.
6. Airlifter performance, including fuel usage (26).

The results of these tests were presented as a series of five tutorials to ASD/XRM. The conclusion drawn from these tests was that, as far as the eighteen categories were concerned, GAMM was operating as

expected (26). No formal report of these test results was published. In addition, the continued use of GAMM by ASD/XRM, MAC, Lockheed Aeronautical Systems Company, Boeing Military Aircraft Company, and Douglas Aircraft Company has resulted in an ongoing process of face validation and improvement of the model.

Event Validation of GAMM

The lack of formal validation made it necessary to confirm that GAMM performed correctly before the actual experiment was carried out. The technique used to assess GAMM's performance was event validation. Event validation "employs identifiable events or event patterns as criteria against which to compare model and system behaviors" (2:67).

Rather than attempting to validate all aspects of the model, the purpose of the event validation was to ensure that the airlift aspects of GAMM operated as expected. To do this, a number of simple airlift jobs were created. These jobs are described below.

Cargo Description. GAMM contains a number of standard cargo items that have predefined dimensions (9:Sec 2-9). Two of these standard items were used to make up a standard aircraft load:

1. Bulk Cargo Pallets. Bulk cargo 463L pallets in GAMM weigh 4600 lbs and are 104" wide, 84" long, and 96" high. Two bulk cargo pallets were included in the standard aircraft load.
2. Passenger Pallets. Passenger pallets are a notional pallet for the purposes of the GAMM model and are defined as having 23 passengers in a box that is 104" wide, 120" long, and 96" high. The weight of a passenger pallet is 5520 lbs. A single passenger pallet was included in the standard aircraft load.

The total weight of a standard load was 14,720 lbs, and its length was 288 inches. This standard load was considerably less than the maximum load carrying capacity of the C-130 and only used about 60% of the cargo cabin. However, the intent of the standard load was not to test GAMM's handling of aircraft loads near the maximum capacity of the aircraft, but rather to see how a more typical small tactical load was handled.

Scenario Description. For the purpose of this event validation, the aircraft characteristics used were those of the C-130H. The Central American scenario was used, making available 16 aircraft to carry out the airlift jobs. Two major airbases, both suitable for C-130 operations at maximum aircraft weight, were selected as the E/D sites for the airlift jobs. Neither of these airbases were the Central American bed-down base for the C-130 aircraft.

Job Description. A number of simple jobs were developed using the standard aircraft load:

1. Job 1: One standard load moved from one E/D site to another.
2. Job 2: Two standard loads, one at each E/D site to be moved to the other.
3. Job 3: Four standard loads, two at each E/D site to be moved to the other.
4. Job 4: 40 standard loads, 20 at each E/D site to be moved to the other.

Expected Results. The primary output measures for the event validation were the number of total and productive sorties generated by each job. Assuming that one standard load would generate one productive sortie, for each job, the maximum number of productive sorties generated

were expected to equal the number of available standard loads. This was the expected result for Jobs 1 and 2. However, for Jobs 3 and 4, it was anticipated that the actual productive sorties flown would be fewer than the number of standard loads available. This was because a standard load did not fully utilize a C-13Ø, and it was expected that the GAMM loading algorithm would make more effective use of the available capacity. The total number of sorties generated was determined by adding the expected number of relocation flights to the expected number of productive sorties. Table 4 summarizes the expected results.

Table 4. GAMM Event Validation - Expected Sorties Generated

	Productive Sorties	Total Sorties
Job 1	1	3
Job 2	2	6
Job 3	4	12
Job 4	4Ø	72

Actual Results. For each job, a separate job file was created. GAMM was then run with each respective job file using the baseline scenario file. Each run lasted for five days and only one repetition was carried out. All other initializing parameters were as given in Appendix C. The results of these runs are contained in Table 5.

Table 5. GAMM Event Validation - Actual Sorties Generated

	Productive Sorties	Total Sorties
Job 1	1	3
Job 2	2	6
Job 3	4	8
Job 4	43	74

Analysis of Results. The results for Jobs 1 and 2 were as expected. For Job 3, the total number of sorties were less than expected. The output report for this run indicated that only two aircraft had been used, rather than the expected four aircraft. For this job, GAMM was optimizing the number of airlifters being relocated. Because the loads at each base were less than two full aircraft loads, only a single aircraft was sent to each base. After delivering the first load to the other base, the remaining load was uplifted and delivered. By using only two aircraft, the number of unproductive sorties flown to complete this job was four. Had four aircraft been used, eight unproductive sorties that would have been generated. Finally, for Job 4, the number of sorties flown was slightly higher than expected. The output report indicated that it had taken two days to completely deliver all loads. The extra sorties resulted from a number of aircraft returning to their home base because the crew had reached the end of their crew duty period before they could deliver the load.

Summary

No documentation was available concerning the initial verification or validation of GAMM. However, as GAMM was modified and new versions of GAMM were released, a series of tests and, later, a baseline analysis were carried out to ensure that the newest version of GAMM was operating as expected. Both studies concluded that GAMM was performing correctly. No unexpected results or problems were identified by either study. Also, the continued use of GAMM by ASD/XRM, MAC, and three major airframe companies indicates that GAMM has a certain amount of face validity. In addition, event validation techniques were used to confirm

that the airlift aspects of GAMM were operating as expected. The results achieved from the four jobs used in the event validation were either as expected or, if not as expected, could be easily explained.

In conclusion, while no formal verification or validation of GAMM has occurred, all assessments of GAMM have shown that the model is operating as expected.

VI. Experimental Findings and Analysis

Calculation of The Required Number of Replications

The purpose of this section of the experiment was to calculate the minimum number of replications required to ensure that the measures used in this analysis were within a specified level of accuracy.

To do this, ten independent, single simulation runs were carried out. To ensure independence, each simulation run was required to use a different random number stream (3:421). This was achieved by changing the random number seed for each run. The same scenario file was used for all runs. This scenario file was identified as EXPØØ.DØ.

The six measures of effectiveness that were selected for the experiment were used to produce the data for the calculation of the minimum number of replications. However, rather than using ratio on time and ratio delivered, the actual values, in tons, were used for these calculations. The results of the ten runs, together with the random number seeds used in each run, are shown in Table 6.

For each measure of effectiveness, the following calculations were carried out. Beginning with the results from Runs 1 and 2, a sample mean and a sample standard deviation were calculated. Then, the results from Runs 1, 2 and 3 were used to calculate another sample mean and sample standard deviation. Next, the results from Runs 1, 2, 3 and 4 were used. This process continued, with the sample size increasing by one run, until all ten results had been included.

For each measure of effectiveness, the mean over all ten runs was used to set the required level of accuracy. Not knowing how accuracy

Table 6. GAMM Model Replications - Results of Ten Independent Runs

Input file used for all replications was EXPØØ.DØ

	TONS ON TIME	TONS DELIVERED	TOTAL FLT HRS	TOTAL SORTIES	PRODUCTIVE FLT HRS	PRODUCTIVE SORTIES
RUN 1	2124	5759	4Ø49	7291	46Ø	845
RUN 2	2158	59Ø7	4Ø21	7294	467	865
RUN 3	2175	5723	4Ø73	7426	447	831
RUN 4	2152	58Ø1	4Ø4Ø	73Ø5	454	847
RUN 5	2167	5785	3993	7226	467	863
RUN 6	21Ø4	5792	41Ø7	7431	449	835
RUN 7	2183	583Ø	3999	7184	462	851
RUN 8	2159	5888	4Ø61	7289	472	872
RUN 9	2158	5794	4Ø83	729Ø	467	865
RUN 1Ø	2142	5828	4Ø66	7312	467	862

RANDOM NUMBER SEEDS:

RUN 1:	PK=2Ø164293Ø2	OTHER=613743814
RUN 2:	PK=2Ø264293Ø2	OTHER=623743814
RUN 3:	PK=2Ø364293Ø2	OTHER=633743814
RUN 4:	PK=2Ø464293Ø2	OTHER=643743814
RUN 5:	PK=2Ø564293Ø2	OTHER=653743814
RUN 6:	PK=2Ø664293Ø2	OTHER=663743814
RUN 7:	PK=2Ø764293Ø2	OTHER=673743814
RUN 8:	PK=2Ø864293Ø2	OTHER=683743814
RUN 9:	PK=2Ø964293Ø2	OTHER=693743814
RUN 1Ø:	PK=21Ø64293Ø2	OTHER=6Ø3743814

would affect the number of replications required, a number of different levels of accuracy were selected. For the accuracy level to be consistent across all the measures of effectiveness, it was initially specified as a percentage, ranging from 1% to 5% of the mean. The actual value was then calculated for each measure of effectiveness and used as the value for ε in Equation 3 reproduced below.

$$R \geq \left(\frac{t_{\alpha/2,R-1} S_0}{\varepsilon} \right)^2 \qquad (3)$$

The value calculated for the sample standard deviation was used as the value for S_0.

The last variable needed was the value of α, which represented the probability of achieving the desired level of accuracy. For all calculations, α was selected as (1 - Ø.95). That is, for a given number of replications, there was a probability of Ø.95 that the results were within the specified accuracy of the 'true' values. Using this value of α, values for t could be determined.

Table 7 shows an extract of the calculations for two output measures, Tons On Time and Tons Delivered. The calculations have used an accuracy value of 2%. The t values used are listed at the bottom of the table. A complete listing of the results of all the calculations carried out is contained in Appendix E.

<u>The Required Number of Replications - Interpretation of Results</u>

Using the results from Table 7, it can be seen that for four cumulative runs, the number of runs required for Tons On Time is 2.45,

Table 7. Extract of Calculations for Determining the Required Number of Replications

NUMBER OF CUMULATIVE RUNS		TONS ON TIME	NUMBER OF RUNS REQUIRED	TONS DELIVERED	NUMBER OF RUNS REQUIRED
2	MEAN	2141.00		5833.00	
2	STDS	24.04	50.36	104.65	130.91
3	MEAN	2152.33		5796.33	
3	STDS	25.96	6.73	97.51	13.03
4	MEAN	2152.25		5797.50	
4	STDS	21.20	2.45	79.65	4.75
5	MEAN	2155.20		5795.00	
5	STDS	19.51	1.58	69.20	2.73
6	MEAN	2146.66		5794.50	
6	STDS	27.22	2.64	61.91	1.87
7	MEAN	2151.85		5799.57	
7	STDS	28.39	2.60	58.09	1.49
8	MEAN	2152.75		5810.62	
8	STDS	26.41	2.10	62.20	1.60
9	MEAN	2153.33		5808.77	
9	STDS	24.76	1.76	58.45	1.34
10	MEAN	2152.20		5810.70	
10	STDS	23.62	1.54	55.44	1.16

ε = 2%	43.044		116.214	
α = 95%				
n =	2	3	4	5
$t(\alpha/2, n-1)$=	12.706	4.303	3.182	2.776
6	7	8	9	10
2.571	2.447	2.365	2.306	2.262

and for Tons Delivered is 4.75. This indicates that four replications are sufficient to achieve an accuracy for Tons On Time within 2% of the actual value with a probability of 0.95. However, for Tons Delivered, the value of 4.75 indicates that more than four replications are required to achieve this level of accuracy. Table 7 indicates that at least five replications would be required.

In general, if the value for the number of runs required is larger than the number of runs used in the sample, then more replications are needed to achieve the indicated level of accuracy. If the value for the number of runs required is smaller than the number of runs used in the sample, then the required level of accuracy will be achieved by carrying out as many replications as there were number of runs in the sample.

Table 7 also shows that the number of runs needed to achieve a specified level of accuracy changes for each measure of effectiveness. Said in another way, for a given number of replications, the accuracy of each measure of effectiveness is different. This is evident when comparing the calculations for different levels of accuracy. These calculations are contained in Appendix E.

Because no level of accuracy had been specified for the experiment, the aim was to select the smallest number of replications that would result in acceptably high accuracy for most of the measures of effectiveness. From the results in Appendix E:

1. Nine replications would be required to achieve an accuracy of 1% for four of the six measures of effectiveness.
2. Five replications would be required to achieve an accuracy of 2% for four of the six measures of effectiveness.
3. Four replications would be required to achieve an accuracy of 3% for all six measures of effectiveness.

Based on these results, each design point in the experiment would be replicated five times. Using five replications rather than nine would increase the half length, ϵ, from 1% to 2%, but it would also reduce total run time by 44%. The slight loss of accuracy was

considered a reasonable price to achieve a considerable reduction in total runtime. The four replication option was not selected because the slight reduction in run time, from 5 to 4 replications, was not considered to be worth the cost of an additional loss of accuracy.

With five replications, four output measures would be accurate to within 2% at a 95% confidence level: Tons On Time, Tons Delivered, Total Flight Hours, and Total Sorties. The other two measures, Productive Flight Hours and Productive Sorties, would be accurate to within 3%.

Experimental Results

To ensure genuinely replicated runs in the experiment, different random number seeds were used for each run. These are listed in Appendix F. The actual results from the 64 runs are shown in Table 8.

Each measure of effectiveness shows considerable variation in range across the 64 runs:

1. Ratio on Time varies from a low value of Ø.12 to a high value of Ø.49.
2. Ratio Delivered varies from a low value of Ø.26 to a high value of Ø.98.
3. Total Flight Hours vary from 594 to 5824.
4. Total Sorties vary from 198Ø to 11Ø15.
5. Productive Flight Hours vary from 55 to 618.
6. Productive Sorties vary from 321 to 1132

For the two main measures of effectiveness, Ratio on Time and Ratio Delivered, the higher values were consistent with the results achieved in the ATTMA C-13Ø deficiency analysis for the modified C-13Ø airlifter (24:Sec 3.4 44-48).

Table 8A. Experimental Results : GAMM Central American Scenario

Test Condition Number	Run No	MAIN EFFECTS A	F	C	I	G	S	Ratio On Time	Ratio Delivered	Total Flight Hours	Total Sorties	Productive Flight Hours	Productive Sorties
1	EXP 19	−	−	−	−	−	−	0.12	0.26	1106	2494	111	331
2	EXP 51	+	−	−	−	−	−	0.12	0.26	1579	3509	120	352
3	EXP 03	−	+	−	−	−	−	0.12	0.26	1127	2544	109	327
4	EXP 35	+	+	−	−	−	−	0.12	0.26	1548	3423	122	356
5	EXP 27	−	−	+	−	−	−	0.19	0.52	960	2032	295	596
6	EXP 59	+	−	+	−	−	−	0.22	0.55	1324	2712	381	708
7	EXP 11	−	+	+	−	−	−	0.19	0.51	939	1980	290	592
8	EXP 43	+	+	+	−	−	−	0.22	0.55	1289	2627	389	710
9	EXP 23	−	−	−	+	−	−	0.12	0.26	594	2650	55	324
10	EXP 55	+	−	−	+	−	−	0.12	0.26	679	2994	55	321
11	EXP 07	−	+	−	+	−	−	0.12	0.26	591	2618	55	324
12	EXP 39	+	+	−	+	−	−	0.12	0.26	659	2906	55	323
13	EXP 31	−	−	+	+	−	−	0.19	0.52	636	2495	222	870
14	EXP 63	+	−	+	+	−	−	0.22	0.54	866	3206	288	993
15	EXP 15	−	+	+	+	−	−	0.19	0.51	632	2484	218	860
16	EXP 47	+	+	+	+	−	−	0.22	0.54	867	3198	294	1004
17	EXP 17	−	−	−	−	+	−	0.19	0.48	3128	5800	448	816
18	EXP 49	+	−	−	−	+	−	0.20	0.50	4831	9211	511	918
19	EXP 01	−	+	−	−	+	−	0.19	0.50	3210	5892	415	758
20	EXP 33	+	+	−	−	+	−	0.21	0.53	4808	9140	499	901
21	EXP 25	−	−	+	−	+	−	0.38	0.90	1484	2881	604	1097
22	EXP 57	+	−	+	−	+	−	0.42	0.91	1637	3120	618	1132
23	EXP 09	−	+	+	−	+	−	0.38	0.92	1424	2742	584	1052
24	EXP 41	+	+	+	−	+	−	0.44	0.95	1635	3088	615	1111
25	EXP 21	−	−	−	+	+	−	0.19	0.47	1551	5390	186	670
26	EXP 53	+	−	−	+	+	−	0.19	0.51	1982	7189	215	786
27	EXP 05	−	+	−	+	+	−	0.19	0.52	1534	5275	203	738
28	EXP 37	+	+	−	+	+	−	0.20	0.56	1867	6717	223	820
29	EXP 29	−	−	+	+	+	−	0.38	0.92	742	2977	287	1028
30	EXP 61	+	−	+	+	+	−	0.42	0.92	813	3244	288	1049
31	EXP 13	−	+	+	+	+	−	0.39	0.92	696	2801	265	941
32	EXP 45	+	+	+	+	+	−	0.44	0.95	802	3143	279	990

Table 6B. Experimental Results : GAMM Central American Scenario

MAIN EFFECTS

Test Condition Number	Run No	A	F	C	I	G	S	Ratio On Time	Ratio Delivered	Total Flight Hours	Total Sorties	Productive Flight Hours	Productive Sorties
33	EXP 18	-	-	-	-	-	+	0.12	0.26	1328	3142	109	330
34	EXP 50	+	-	-	-	-	+	0.12	0.26	1769	4003	117	346
35	EXP 02	-	+	-	-	-	+	0.12	0.26	1282	2876	118	349
36	EXP 34	+	+	-	-	-	+	0.12	0.26	1496	3303	120	355
37	EXP 26	-	-	+	-	-	+	0.21	0.56	1076	2282	333	691
38	EXP 58	+	-	+	-	-	+	0.23	0.58	1278	2618	401	757
39	EXP 10	-	+	+	-	-	+	0.21	0.56	1067	2245	337	680
40	EXP 42	+	+	+	-	-	+	0.23	0.58	1370	2804	400	756
41	EXP 22	-	-	-	+	-	+	0.12	0.26	688	3054	55	327
42	EXP 54	+	-	-	+	-	+	0.12	0.26	779	3489	56	328
43	EXP 06	-	+	-	+	-	+	0.12	0.26	695	3075	56	328
44	EXP 38	+	+	-	+	-	+	0.12	0.26	785	3508	56	328
45	EXP 30	-	-	+	+	-	+	0.20	0.52	682	2619	227	888
46	EXP 62	+	-	+	+	-	+	0.22	0.55	903	3290	306	1040
47	EXP 14	-	+	+	+	-	+	0.20	0.52	674	2587	226	881
48	EXP 46	+	+	+	+	-	+	0.22	0.55	873	3178	303	1038
49	EXP 16	-	-	-	-	+	+	0.20	0.53	3958	7222	482	897
50	EXP 48	+	-	-	-	+	+	0.22	0.57	5824	11015	570	1051
51	EXP 00	-	+	-	-	+	+	0.21	0.56	4049	7287	456	848
52	EXP 32	+	+	-	-	+	+	0.23	0.61	5719	10732	553	1020
53	EXP 24	-	-	+	-	+	+	0.41	0.93	1488	2868	601	1091
54	EXP 56	+	-	+	-	+	+	0.44	0.92	1569	2996	592	1087
55	EXP 08	-	+	+	-	+	+	0.42	0.93	1430	2757	559	1024
56	EXP 40	+	+	+	-	+	+	0.48	0.97	1615	3003	594	1082
57	EXP 20	-	-	-	+	+	+	0.20	0.52	1890	6586	204	746
58	EXP 52	+	-	-	+	+	+	0.20	0.54	2245	8179	220	808
59	EXP 04	-	+	-	+	+	+	0.21	0.58	1902	6530	224	816
60	EXP 36	+	+	-	+	+	+	0.21	0.61	1890	6786	240	892
61	EXP 28	-	-	+	+	+	+	0.42	0.94	758	3063	285	1025
62	EXP 60	+	-	+	+	+	+	0.45	0.93	805	3169	286	1035
63	EXP 12	-	+	+	+	+	+	0.43	0.94	687	2731	261	932
64	EXP 44	+	+	+	+	+	+	0.49	0.98	799	3075	282	991

The results for each measure of effectiveness were used to calculate estimates of the main and interaction effects of the variables. As described in Chapter IV, two methods were used: Yate's Algorithm and the Difference between Two Averages. The calculations for the Yate's Algorithm are contained in Appendix G. The results of the Difference between Two Averages method are contained in Appendix H. Each method should produce the same estimates for the main and interaction effects of the variables. However, both methods were used to ensure the accuracy of the results.

Transformation of Data

When "Y_{max}/Y_{min} is large", it is possible that some form of transformation may produce a "simplified and more efficient representation" (4:334). The results of the experimental runs had very large differences between the largest and the smallest values. In addition, the initial analysis of residuals, using a plot of the residuals against the predicted results, indicated that the residuals were heteroscedastic. That is, the residuals displayed non-constant variance, with the standard deviation of the residuals increasing as the value of the predicted result increased.

To correct the possible problems that this would cause in the analysis, it was decided to transform the data using the natural logarithm transformation. All the results from the experiment were converted to their values in natural logarithms. These values are contained in Appendix K. The transformed results were then used to calculate new estimates for the main and interactive effects of the variables. Again, both Yate's Algorithm and the Difference between Two

Averages methods were used. For the transformed results, the calculations for the Yate's Algorithm are contained in Appendix I, and the results for the Difference between Two Averages are contained in Appendix J.

Identification of Significant Terms

Appendix J also lists the estimate of the standard error for each output measure. This was calculated from the sum of squares of the estimates of all the three, four, five and six factor interaction effects.

As mentioned in Chapter IV, all terms whose estimates had an absolute value greater than three times the standard error were considered to have a statistically significant effect on the value of the output. These terms and their estimates were used to develop a regression model for each measure of effectiveness. The regression model, previously discussed in Chapter IV, is shown below.

$$\hat{y} = \bar{y} + \left(\frac{\beta_1}{2}\right)x_1 + \left(\frac{\beta_2}{2}\right)x_2 + \ldots + \left(\frac{\beta_n}{2}\right)x_n \tag{5}$$

where

$\hat{y}$ = *the estimate of the output*

$\bar{y}$ = *the estimate of the average output across all experimental runs*

β_n = *the estimate of the effect of the nth term calculated by Yate's algorithm*

x_n = *the nth term*

Regression equations for all six measures of effectiveness were developed using the estimates produced from the transformed results. However, to compare the effect of the transformation on the analysis, an additional regression equation was developed for one measure, Ratio on Time, using the original, untransformed results of the experiment. The seven initial regression equations are listed in Figure 9 below.

Using these seven equations, ANOVA tables were constructed and an analysis of residuals was carried out. The full ANOVA tables and the residual plots are contained in Appendix L. However, the important values from the ANOVA table, the F value and the Adjusted R^2 value, for the seven equations are summarized in Table 9 below.

Table 9. Summary of ANOVA Tables for Initial Regression Equations

MEASURE OF EFFECTIVENESS	F VALUE	ADJUSTED R^2
Ratio On Time Eqn 1	1443.848	0.995653
Ratio On Time (Ln) - Eqn 2	2331.128	0.997304
Ratio Delivered - Eqn 1	2446.741	0.997146
Total Flight Hours - Eqn 1	456.495	0.984856
Total Sorties - Eqn 1	284.491	0.972987
Productive Flight Hours - Eqn 1	1524.693	0.995427
Productive Sorties - Eqn 1	757.536	0.989700

The results from the ANOVA table indicate that all seven of the regression equations provide an extremely good fit of the actual results. In addition, the plots of residuals for the seven equations, shown in Appendix L, indicate that the residuals are randomly scattered about zero, and the normal probability plots of the residuals for the seven equations closely approximate a straight line, indicating that the residuals are approximately normally distributed about zero. Overall,

Ratio On Time Function - Equation 1

$$\hat{y}=0.239219+(0.020313/2)A+(0.006562/2)F+(0.155938/2)C+(0.148437/2)G$$
$$+(0.015312/2)S+(0.065938/2)CG+(0.015313/2)AC+(0.007812/2)AG$$
$$+(0.007812/2)CS+(0.010312/2)GS$$

Ratio On Time Function - Equation 2

$$Ln(\hat{y})=-1.535428+(0.069347/2)A+(0.019679/2)F+(0.647986/2)C$$
$$+(0.612359/2)G+(0.052023/2)S+(0.090673/2)CG+(0.045037/2)AC$$
$$+(0.019679/2)FG+(0.027544/2)GS+(0.018423)CIG$$

Ratio Delivered Function - Equation 1

$$Ln(\hat{y})=-0.664018+(0.03274/2)A+(0.025351/2)F+(0.643881/2)C$$
$$+(0.633737/2)G+(0.041477/2)S+(0.027778/2)FG$$
$$+(-0.088493/2)CG+(-0.024146/2)ACG+(-0.031459/2)CGS$$

Total Flight Hours Function - Equation 1

$$Ln(\hat{y})=7.163+(0.214/2)A+(-0.501/2)C+(-0.671/2)I+(0.607/2)G$$
$$+(0.087/2)S+(0.112/2)CI+(-0.462/2)CG$$
$$+(-0.106/2)IG+(0.054/2)ACI$$

Total Sorties Function - Equation 1

$$Ln(\hat{y})=8.197+(0.205/2)A+(-0.526/2)C+(0.493/2)G+(0.084/2)S$$
$$+(0.114/2)CI+(-0.082/2)IG+(-0.365/2)CG+(-0.068/2)ACG$$

Productive Flight Hours Function - Equation 1

$$Ln(\hat{y})=5.469+(0.115/2)A+(0.778/2)C+(-0.657/2)I+(0.851/2)G$$
$$+(0.124/2)CI+(-0.547/2)CG+(-0.136/2)IG$$
$$+(-0.080/2)ACG+(-0.089/2)CIG$$

Productive Sorties Function - Equation 1

$$Ln(\hat{y})=6.544+(0.085/2)A+(0.547/2)C+(0.589/2)G+(0.107/2)CG$$
$$+(-0.122/2)IG+(-0.33/2)CG+(-0.055/2)ACG+(-0.08/2)CIG$$

Legend:
A. Aircraft Numbers
C. Cargo Cabin
G. Ground Flotation/Wheel Loading
S. Servicing and Aircraft Loading/Unloading
F. Field Performance
I. Inflight Performance

Figure 9. Initial Regression Equations

these regression equations proved to be extremely accurate statistical models for representing the results of each measure of effectiveness.

Identification of Relevant Terms

Although the models were very accurate, they were not very useful. As can be seen from Figure 9, each of the regression equations contained between eight and ten terms and, except for one equation, these terms used five or more of the six variables in the experiment. Four or five terms of each equation were interaction terms and all but one equation contained a three factor interaction term.

The initial regression equations had included all the statistically significant terms. However, while these terms may have been significant by comparison to the higher order interactions used to calculate the standard error, they may not all be significant to the response function being modeled.

For the purpose of this analysis, parsimonious models were required. Rather than developing extremely accurate models, this analysis was attempting to identify the smallest number of significant terms that would still provide an adequate representation of the response function for each measure of effectiveness.

The parsimonious models were developed in the following manner:

1. Beginning with the initial regression equation for each measure of effectiveness, three or four terms, whose coefficients had the smallest absolute values, would be removed from the equation.
2. New ANOVA tables and new residual plots would be constructed from these reduced equations.

The results from the reduced equations were then compared with the initial regression equations to determine whether any significant terms had been removed. If the results showed that no significant terms had been removed, this process was repeated. The ANOVA tables and the residual plots for all the reduced equations that were developed in this manner are contained in Appendix M.

A final set of parsimonious regression equations was eventually developed and is presented in Figure 10 below. The F values and the Adjusted R^2 values from the ANOVA tables for these seven equations are summarized in Table 10 below.

Table 10. Summary of ANOVA Tables for Parsimonious Regression Equations

MEASURE OF EFFECTIVENESS	F VALUE	ADJUSTED R^2
Ratio On Time - Eqn 5	754.795	0.972896
Ratio On Time (Ln) - Eqn 3	1210.546	0.982935
Ratio Delivered - Eqn 3	2109.084	0.990137
Total Flight Hours - Eqn 3	192.756	0.924042
Productive Flight Hours - Eqn 3	434.984	0.964977
Total Sorties - Eqn 4	143.802	0.871897
Productive Sorties - Eqn 3	300.056	0.934363

These results indicate that all seven of the parsimonious equations provided a good fit of the actual results. The plots of residuals for the seven equations, shown in Appendix M, clearly show the effect of the reduced number of terms. As the number of terms were reduced, the number of values that were possible for the estimated result decreased. Five of the equations contain only two variables, allowing only four possible values for the estimated result. The residuals were still reasonably well scattered about zero, even though the plots were distinctly bunching together, as expected, around the

Ratio On Time Function - Equation 5

$$\hat{y}=0.239219+(0.155938/2)C+(0.148437/2)G+(0.065938/2)CG$$

Ratio On Time Function - Equation 6

$$Ln(\hat{y})=-1.535428+(0.647986/2)C+(0.612359/2)G+(0.090673/2)CG$$

Ratio Delivered Function - Equation 3

$$Ln(\hat{y})=-0.664018+(0.643881/2)C+(0.633737/2)G+(0.088493/2)CG$$

Total Flight Hours Function - Equation 3

$$Ln(\hat{y})=7.163+(-0.501/2)C+(-0.671/2)I+(0.607/2)G+(-0.462/2)CG$$

Productive Flight Hours Function - Equation 3

$$Ln(\hat{y})=5.469+(0.778/2)C+(-0.657/2)I+(0.851/2)G+(-0.547/2)CG$$

Total Sorties Function - Equation 4

$$Ln(\hat{y})=8.197+(-.526/2)C+(.493/2)G+(-.365/2)CG$$

Productive Sorties Function - Equation 3

$$Ln(\hat{y})=6.544+(0.547/2)C+(0.589/2)G+(-0.33/2)CG$$

Legend:
A. Aircraft Numbers
C. Cargo Cabin
F. Field Performance
I. Inflight Performance
G. Ground Flotation/Wheel Loading
S. Servicing and Aircraft Loading/Unloading

Figure 10. Parsimonious Regression Equations

fewer estimated response values. The normal probability plots also lost their extremely close approximation to straight lines as the number of terms in the equations decreased, but the plots were still reasonably straight. This indicated that the values of the residuals could not be completely attributed to random noise, and that some factor existed that was statistically significant. Since all the terms removed from the equation had been statistically significant, this result was not surprising.

All the coefficients in the equations for Ratio on Time and Ratio Delivered are positive. This means that when either variable is changed from a low level to a high level, the value of the result will increase. If both variables are changed, the value will increase by an even greater amount because then the interaction term will be positive as well.

For the other measures of effectiveness, the results are not as clear because of the significant interaction term, CG. The results are more clearly shown in following sections.

Comparison of the Transformed Results

As mentioned earlier in this chapter, the calculations for the regression analysis of Ratio On Time were carried out using both the original results from the experiment and the transformed results. The purpose of this comparison is to confirm that the transformation used did provide a better representation of the response function.

The two initial regression equations for Ratio On Time, listed in Figure 9, contain 8 common terms. Only two interaction terms in each were different. These different terms were also the first terms removed

from the equations as the parsimonious models were being developed, and as Figure 10 shows, the final equations contained the same terms.

To determine whether the transformed model was a better model, it was necessary to compare the results from the ANOVA tables and the residual analysis for each equation. The main results from the ANOVA tables are reproduced in Table 11 below. As can be seen in Table 11, for each set of comparable equations, the model developed from the transformed results proved to be a better model than the model developed from the untransformed results. By comparing the residual plots in Appendices L and M, it is evident that the problem of non-constant variance that existed with the untransformed residuals has been largely

Table 11. Comparison of Results for Ratio On Time

	F VALUE	ADJUSTED R^2
INITIAL REGRESSION EQUATION		
Ratio On Time - Eqn 1	1443.848	0.995653
Ratio On Time (Ln) - Eqn 2	2331.128	0.997304
FIRST REDUCTION		
Ratio On Time - Eqn 3	1061.041	0.990192
Ratio On Time (Ln) - Eqn 4	2072.789	0.994958
FINAL EQUATION		
Ratio On Time - Eqn 5	754.795	0.972896
Ratio On Time (Ln) - Eqn 6	1210.546	0.982935

solved by the transformation, further confirming that the transformation has produced a better model.

Interpretation of Results

For four of the six measures of effectiveness, the parsimonious models that were developed contained only three terms. These three terms contained only two of the six variables used in the experiment.

The two variables were C, the cargo cabin size, and G, the aircraft's ground flotation/wheel loading. The models for the other two measures of effectiveness both contained a single additional term, containing the variable I, the inflight performance of the aircraft.

All six equations contained the interaction term CG. When interpreting the results for each measure of effectiveness, the effects of the variables in the interaction term must be considered jointly (4:328).

The high and low levels of C and G result in four possible combinations of these two variables within the interaction term, CG. From the 64 runs carried out, 16 results were available for each of the four combinations. The 16 results were used to calculate an average value for each combination of C and G in the interaction term. For each of the measures of effectiveness, these results have been plotted in the figures below. The top line in each of the figures represents the high level of the variable C. This line can be considered to represent a large tactical airlifter. The lower line therefore represents a small tactical airlifter.

Ratio On Time. The effects of the two variables, C and G, on the results for the Ratio On Time are shown in Figure 11 below. The effect of the interaction is clearly seen. Increasing the size of the cargo cabin results in a much greater increase in the ratio of cargo delivered on time when the flotation variable, G, is at a high level rather than a low level.

Ratio Delivered. A similar result is shown in Figure 12 for Ratio Delivered. While there are still indications of the effect of the

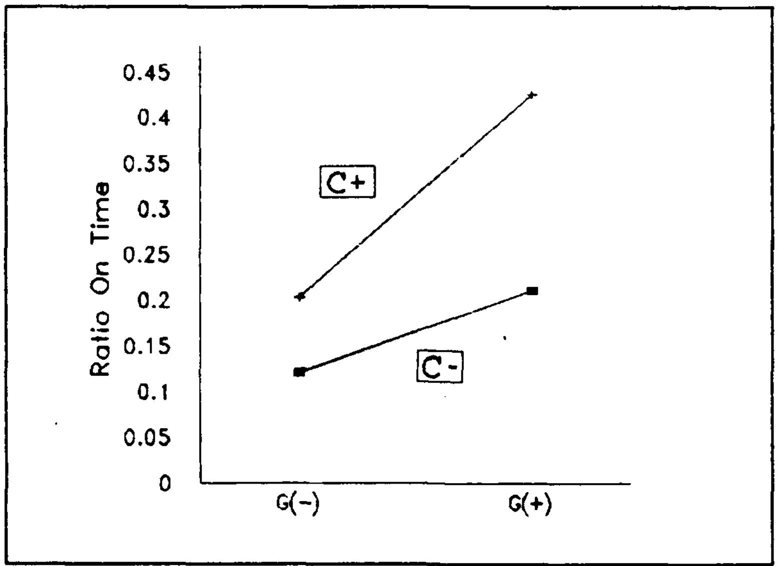


Figure 11. Interaction Effect - Ratio On Time

interaction, it is not as pronounced as in Figure 11. However, the figure does show that significant increases in the ratio of cargo delivered occur when either variable is increased from its low level to its high level, and the greatest increase occurs when both variables are set to their high levels.

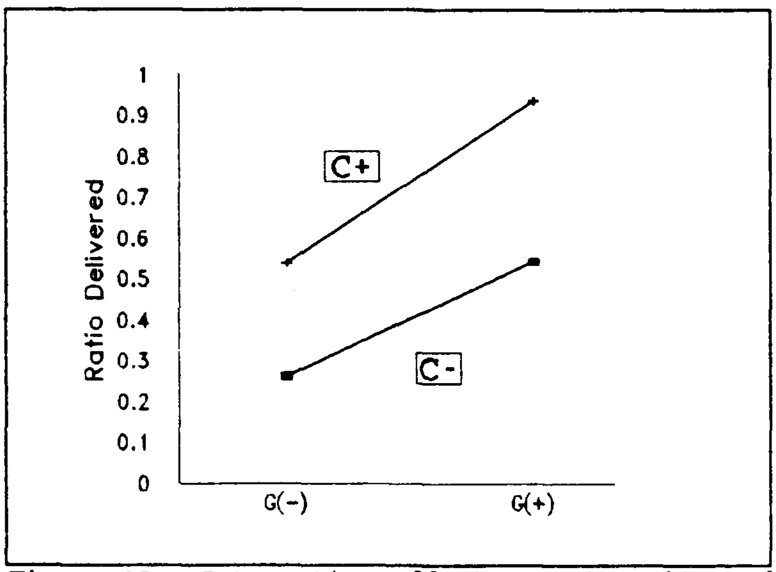


Figure 12. Interaction Effect - Ratio Delivered

Total Sorties Flown. Figure 13 shows the results for this measure of effectiveness. The impact of the interaction term on the results of this measure of effectiveness is extremely large. Looking at Figure 13 in isolation might imply that a large aircraft with a low level of G will fly thousands of additional sorties trying to carry out all the required airlift tasks. By changing the value of G to the high level, the larger aircraft reduces the number of sorties to nearly one third of the previous amount. The change of G for the smaller aircraft also results in a reduction in the total number of sorties flown, but the reduction is small compared to that for the larger aircraft.

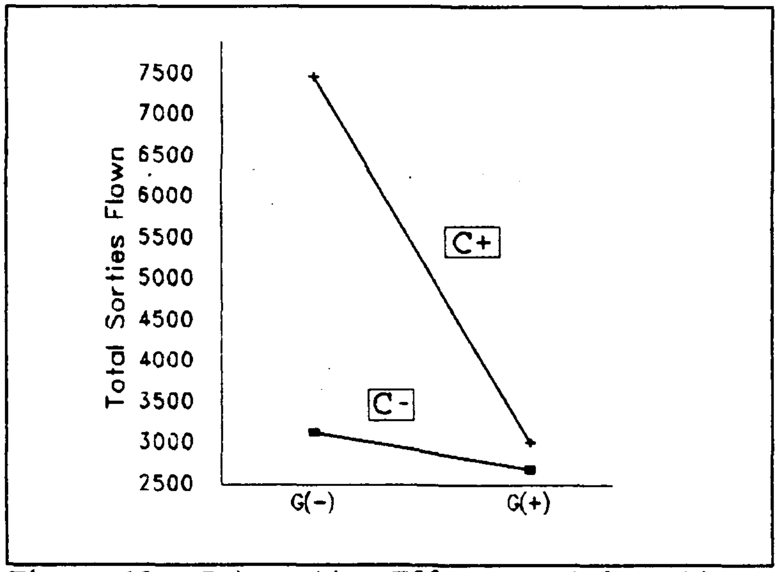


Figure 13. Interaction Effect - Total Sorties Flown

Comparing Figure 13 to the results for the previous two figures reveals the true effect of the changes. For the larger aircraft, the change in the level of G to the higher level not only reduced the total sorties flown to one third, but also doubled the total cargo delivered and the total cargo delivered on time, resulting in a six fold increase

in productivity. For the smaller aircraft, the smaller reduction in total sorties together with the doubling of the total cargo delivered and total cargo delivered on time resulted in an almost three fold increase in productivity.

Productive Sorties. The effects of the variables C and G on the number of productive sorties is shown in Figure 14. In this case, the interaction effect appears to affect the smaller aircraft much more than the larger aircraft.

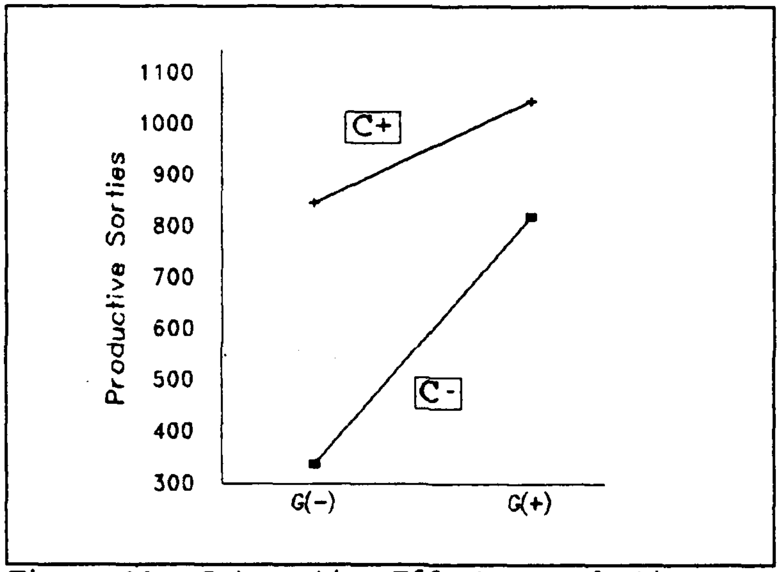


Figure 14. Interaction Effect - Productive Sorties Flown

Total Flight Hours. From the regression equation in Figure 10, it can be seen that as the variable I changes from low level to high level, that is, as the inflight performance of the aircraft improves, the total flight hours decrease. This was not an unexpected result. The effect of the variables C and G is shown in Figure 15. As expected, these results closely match the results for Total Sorties Flown, and similar comments can be made about these results.

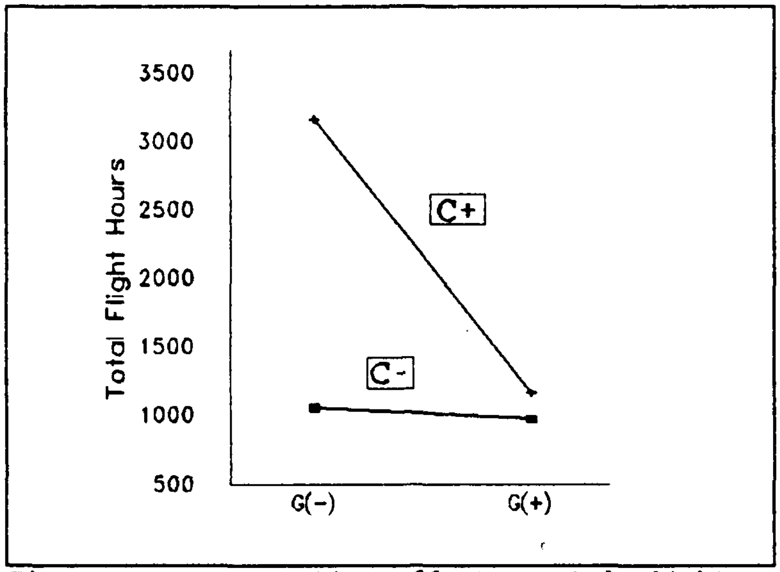


Figure 15. Interaction Effect - Total Flight Hours

Productive Flight Hours. The regression equation for Productive Flight Hours also contains a negative coefficient for the variable I. Hence as the inflight performance improves, the number of productive flight hours will decrease. Figure 16 shows the effects of the other

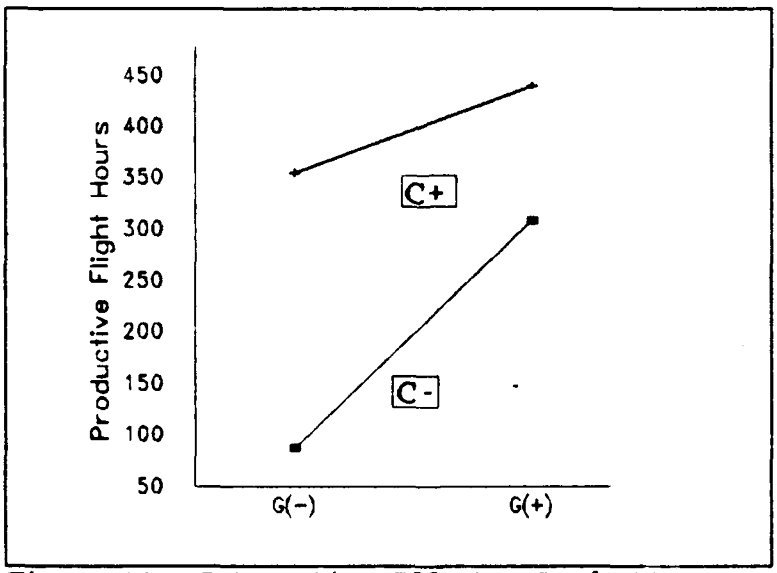


Figure 16. Interaction Effect - Productive Flight Hours

two variables. The results for Productive Flight Hours also closely matches the result for Productive Sorties Flown.

Analysis of the Interaction Term

The presence of significant interaction terms in the final models was not anticipated. That the same interaction term should occur in every model was completely unexpected. The only reason that this could have occurred would be due to some significant link between the two variables C and G.

When the aircraft parameters that made up these two variables were initially selected, no links appeared to exist. However, on closer examination, a possible connection was identified. The variable G contains just two parameters, both LCN values that GAMM uses to determine whether an aircraft can operate onto a given airfield. In addition to this, GAMM uses the LCN values to determine the largest useful load that can be supported by the given airfield (9:Sec 3-1). One value of LCN is given at the maximum useful load and the other value of LCN is given at zero useful load. The variable C contains the value of maximum useful load. Using this value, GAMM interpolates between the high and low values of an aircraft's LCN to determine the maximum load that can be supported by a given airfield. For a scenario such as Central America where the majority of the airfields are restricted by LCN rather than by runway length, the aircraft's LCN values and its maximum useful load become very important.

This link between maximum useful load and the aircraft's LCN results in the very significant interaction between the C and G variables.

Summary

In choosing a value for the minimum number of replications for each design point in the experiment, a trade off was required between the desired level of accuracy of the results and the total run time required to achieve a given level of accuracy. For this experiment, five replications were selected. For four of the measures of effectiveness, five replications would result in an accuracy of better than 2% with 95% confidence. For the other two measures, an accuracy of better than 3% could be achieved.

The analysis of the experimental results produced a parsimonious model for each of the six measures of effectiveness. Surprisingly, all the models contained the same two variables: the Cargo Cabin variable C, and the Ground Flotation/Wheel Loading variable G. These were the only variables in the models for four of the measures of effectiveness. The models for the other two measures, Total Flight Hours and Productive Flight Hours, also contained one other variable, Inflight Performance.

The effect of Inflight Performance on Flight Hours was as expected. An increase in the Inflight Performance reduced the number of hours flown. The effect of the variables C and G on each of the measures of effectiveness could not be as easily explained because all the models contained these variables in an interaction term.

However, for the two primary measures of effectiveness, Ratio On Time and Ratio Delivered, it was clear that a significant improvement in the throughput of the tactical airlift system could be achieved by using aircraft with a high level of C and a high level of G.

VII. Conclusions and Recommendations

Summary of Experiment

The purpose of this study was to identify a specific set of tactical airlifter characteristics that would result in the greatest improvement in tactical airlift capability. The Generalized Air Mobility Model (GAMM) was used to simulate a tactical airlift system operating within a predetermined scenario in Central America.

Because the response of the airlifter characteristics on tactical airlift capability was not known, a two level full factorial experimental design was chosen to carry out the screening experiment. A large number of significant aircraft parameters were available in GAMM. Because it was not possible to test each individual parameter using a two level full factorial experiment, it was decided that the existing parameters would be grouped in five functional sets, identified as Field Performance, Cargo Cabin, Inflight Performance, Ground Flotation/Wheel Loading, and Servicing and Aircraft Loading/Unloading. These five sets became five of the six variables used in the experiment. The sixth variable used in the experiment was Aircraft Numbers.

After the experimental runs had been carried out, the results were transformed and, for each of the measures of effectiveness that had initially been selected, a parsimonious model was developed. The variables remaining in these models identified the set of aircraft parameters that were found to be significant.

Results

Two variables appeared in all six of the models developed. For four of the six models, only these two variables were present in the terms of the model. In the other two models, only one additional variable was present. The variables, and the aircraft parameters that made up those variables are listed in Table 12 below.

Table 12. Summary of Significant Airlifter Characteristics - Central American Scenario

EXPERIMENTAL VARIABLE	AIRCRAFT PARAMETER
Cargo Cabin (C)	Cargo Bay Width Cargo Bay Height Cargo Bay Length Cargo Bay Door Width Cargo Bay Door Height CTOL Max Useful Load CTOL Mid Useful Load Maximum Cabin Payload Aircraft Spot Factor Cargo Threshold for Relocation
Ground Flotation/Wheel Loading (G)	LCN - Max Useful Load LCN - At Zero Useful Load
Inflight Performance (I)	Maximum Ferry Fuel Cruise Fuel Cruise Speed Takeoff/Landing Fuel Bias

The variables C and G were the only variables in the models that represented Ratio On Time, Ratio Delivered, Total Sorties Flown and Productive Sorties. All three variables appeared in the models for Total Flight Hours and Productive Flight Hours.

While the three variables were significant to the models that were developed, all the parameters identified in Table 12 may not necessarily be significant to tactical airlift capability. The design of the

variables for the experiment resulted in the grouping of these parameters, so it was not possible to distinguish between the effects of parameters within a group. To identify individual parameters that are significant, another experiment would be required.

Implications of these Results

For a tactical airlift scenario similar to Central America, where there are many small unprepared strips available, these results indicate that a significant increase in throughput can be achieved for a tactical airlift system by increasing the size of the aircraft's cargo cabin and at the same time improving the aircraft's ability to operate on unprepared airfields. A significant increase in throughput will result in a greater number of tactical airlift jobs being completed on time, and a greater number of airlift jobs being delivered overall.

More importantly, these results show that improving other aircraft characteristics, such as cruise speed or a very short take-off and landing capability, would not significantly improve the throughput of the tactical airlift system in the scenario studied.

Thus, this research identified the areas of tactical airlifter development that will result in significant benefits, as well as those that would be marginally useful for this type of scenario.

Recommendations for Further Research

This study conducted an initial screening of tactical airlifter characteristics. A number of areas are recommended for further research.

1. Twelve parameters were identified as belonging to the two main variables identified in this research. Given that this study found that higher order interaction terms were not significant, it should be possible to design a fractional factorial experiment such as a 2^{12-6} design that would be able to identify which of these twelve parameters are significant.

2. On a more general level, this study made a number of initial assumptions that meant important aspects of the tactical airlift model, such as attrition and maintainability/reliability, were not considered at all. These parameters could be grouped into a number of variable sets as was done in this study. The parameters in the three variables that were found to be insignificant in this study could be ignored. The significant variables identified in this research and the new variables would then be the basis for further research to determine how attrition and maintainability and reliability issues affect the tactical airlift system.

3. One major limitation of the research was that it only used a single scenario. The results from this research therefore have tended to optimize the performance of the tactical airlifter for just this scenario. Since it seems improbable that a new airlifter will be designed just for this environment, it is recommended that further research be carried out using the other available scenarios of Southwest Asia or Europe. Once additional scenarios have been assessed, it may be possible to identify tactical airlifter characteristics that result in an increase in throughput across all the scenarios. It may also be possible to

identify which particular characteristics are scenario dependent and are more important in one scenario than another. It may then be possible to identify a set of characteristics for a tactical airlifter that, if put together in one aircraft, would result in a tactical airlifter that performs well in all scenarios.

4. One additional area for further research is the GAMM model itself. The GAMM model is a very powerful tool for analyzing tactical airlifters. However, during this research, it was only possible to use a small fraction of its capability. In particular, very little experimentation was done with the parameters used in the initialization of the model. Changes to some of these parameters, such as the priority scheduling factor may have significant effects on the outcome of the model. Further research is needed in this area to better define how GAMM responds to changes in these parameters.

Appendix A: GAMM Airlifter Characteristics - Baseline C-130H

AIRLIFTER TYPE	C130H			
	- SEA LEVEL -		- 5000 FEET -	
	HOT 103 F	COLD 59 F	HOT 84 F	COLD 41 F
CTOL MAX USEFUL LOAD (LBS)	72000	72000	72000	72000
CTOL TO AT MAX USEFUL LOAD (FT)	3580	2680	4070	3440
CTOL LD AT MAX USEFUL LOAD (FT)	2280	2150	2570	2430
CTOL MID USEFUL LOAD (LBS)	37000	37000	37000	37000
CTOL TO AT MID USEFUL LOAD (FT)	1980	1620	2340	2010
CTOL LD AT MID USEFUL LOAD (FT)	1890	1800	2100	2000
CTOL TO AT ZERO USEFUL LOAD (FT)	1080	950	1240	1110
CTOL LD AT ZERO USEFUL LOAD (FT)	1500	1420	1640	1530
VTOL MAX USEFUL LOAD (LBS)	0	0	0	0

LCN - MAX USEFUL LOAD (NO)	39
LCN - AT ZERO USEFUL LOAD (NO)	18
MAXIMUM FERRY FUEL (LBS)	59970
MAXIMUM CABIN PAYLOAD (LBS)	50800
CRUISE FUEL (LBS/HR)	5300.
CRUISE SPEED (KNOTS)	236
CARGO BAY WIDTH (INCH)	107
CARGO BAY HEIGHT (INCH)	102
CARGO BAY LENGTH (INCH)	503
CARGO BAY DOOR WIDTH (INCH)	120
CARGO BAY DOOR HEIGHT (INCH)	109
MISSION ESSENTIAL FHBF (HRS)	2.34
NON MISN ESSENTIAL FHBF (HRS)	999.00
MEAN TIME TO REPAIR (HRS)	2.40
MTTR STANDARD DEVIATION (NO)	0.83
MEAN TIME TO SERVICE (HRS)	0.50
MTTS STANDARD DEVIATION (NO)	0.05
MEAN TIME TO LOAD (HRS)	1.00
MTTL STANDARD DEVIATION (NO)	0.10
LOAD FAC FOR ROLLING STOCK (NO)	0.50
MEAN TIME TO UNLOAD (HRS)	0.25
MTTU STANDARD DEVIATION (NO)	0.03
UNLD FAC FOR ROLLING STOCK (NO)	0.50
MEAN TIME TO REPAIR BATTLE DAMAGE (HRS)	92.50
MTTRBD STANDARD DEVIATION (NO)	102.80
AIRCRAFT SPOT FACTOR (NO)	1.00
VULNERABILITY EXPONENT (NO)	1.00
RESERVE FUEL (HRS)	1.00
TAKEOFF/LANDING FUEL BIAS(LBS)	1500.0
PAYLOAD MARGIN NEXT FLT (LBS)	1000.
TAXI, TAKEOFF & LANDING TIME (HRS)	0.25
CARGO THRSHLD FOR RELOCATION (LBS)	15000.
PALLET ROTATION FLAG	NO

Appendix B: Airlift Jobs for Central American Scenario (22:Sec 4-8)

Job No.	Description	Closure Time	Pr'ty 1-Hi	Freq	-Total Tons- Pax/Bulk/Veh	Average Tons/Job	Largest Dimensions L	V	H	Wt	Threat (Km) Close	Farthest
1	UNIT MOVE, LIGHT INF BN (LIB)	24.0	3	2	172/ 12/ 352	268.0	355	99	105	17t	3.0	3.8
2	UNIT MOVE, TRANS CO	24.0	6	1	22/ 0/1331	1353.0	368	99	105	17t	48.4	48.4
3	UNIT MOVE, SPT GP HHC	24.0	6	1	11/ 0/ 54	72.0	320	97	134	7t	48.4	48.4
4	UNIT MOVE, JTF/ALF HQ	24.0	5	1	28/ 0/ 157	185.0	361	99	138	13t	87.3	87.3
5	EMERG RESUPPLY, POL	4.0	3	16	0/1056/ 0	66.0	84	108	96	3t	-18.7	81.9
6	EMERG RESUPPLY TO ARTY UNIT	6.0	3	8	0/1584/ 0	198.0	84	108	96	3t	-19.0	32.8
7	EMERG RESUPPLY, AIRDROP RATIONS	12.0	6	23	0/ 23/ 0	1.0	84	108	96	2t	-25.4	54.4
8	LEAFLET DROP	24.0	7	4	0/ 120/ 0	30.0	84	108	96	2t	-26.9	-8.5
9	PERSONNEL MOVE, REPLACEMENTS	18.0	5	9	783/ 0/ 0	87.0	24	24	72	--	-18.7	87.2
10	EMERG RESUPPLY, CRITICAL EQUIP	12.0	3	19	0/ 0/ 247	13.0	264	95	88	7t	-18.7	84.5
11	EMERG RESUPPLY TO BDE	12.0	5	18	0/1800/ 0	100.0	84	108	96	3t	-18.7	65.1
12	SCHEDULED COURIER SREVICE	24.0	6	242	726/ 484/ 0	5.0	84	108	96	2t	2.6	221.3
13	RTN RESUPPLY, PAX/REPAIR PARTS	24.0	5	32	64/ 480/ 0	17.0	84	108	96	2t	48.2	54.4
14	EVACUATE KIA PERSONNEL	24.0	8	20	0/ 40/ 0	2.0	84	108	96	2t	-18.7	118.1
15	MEDICAL EVACUATION	4.0	2	20	96/ 0/ 0	4.8	24	24	72		-18.8	118.1
16	RETROGRADE EQUIPMENT	24.0	6	14	0/ 0/ 280	20.0	440	96	84	8t	-18.7	119.6

Appendix C: GAMM Initialization Sequence - Baseline Parameters

```
                  GENERALIZED AIR MOBILITY MODEL
                              (GAMM)


                      RELEASE  3 VERSION  5

                      DATE OF LAST REVISION
                            Ø9/Ø4/9Ø



                ENTER CARRIAGE RETURN(CR) TO CONTINUE

INTERACTIVE GRAPHICS (Y/N)? N

CURRENT DEFAULT DISK = DEFAULT:.DAT
CHANGES(Y/N)? N

IS A NEW CHAIN OF SCENARIO INPUTS TO BE CREATED(Y/N)? N

ARE INPUTS TO BE FROM AN EXISTING SCENARIO FILE(Y/N)? Y

IS FILE A CHAIN OF SCENARIOS OR A SINGLE SCENARIO(C/S)? S

ENTER ID OF THE SINGLE SCENARIO > CAMRUNØ3.DØ

    THIS SCENARIO HAS A PREDETERMINED NUMBER OF
    AIRLIFTER TYPES, AIRBASES, E/D SITES, AIRLIFTERS,
    AND FLIGHT PLANNING TIMES.

DO YOU NEED TO CHANGE THESE (Y/N) ? N

INCREMENTAL CHANGES DURING SIMULATION(Y/N)? N

JOBS FILE (Y/N)? Y

ENTER JOBS FILE ID > CAMJOBS.XRM

CURRENT NUMBER OF JOB TYPES =    16
ADD MORE (Y/N)? N

STANDBY - READING DATA

         INPUT DATA MENUS:

              1 FOR ENTRY/DELIVERY SITE DATA
              2 FOR AIRFIELD CHARACTERISTICS
              3 FOR AIRLIFTER CHARACTERISTICS
```

```
          4 FOR AIRLIFTER PERFORMANCE CHECK
          5 FOR AIRLIFTER PS DATA
          6 FOR TRANSPORTATION ARC DATA
          7 FOR SURVIVABILITY JOB SCHEDULER
          8 FOR FLIGHT SCHEDULE
          9 FOR JOB DESCRIPTIONS
         1Ø FOR MOVEMENT REQUESTS
         11 FOR JOB DELETION CONDITIONS
         12 FOR INITIAL CONDITIONS
         13 FOR SAVING DATA
         14 TO CONTINUE

         15 TO STOP/END/EXIT

      ENTER RESPONSE > 14

ENTER LENGTH OF SIMULATION IN DAYS (XX.) > 3Ø.

ENTER NUMBER OF REPETITIONS (1) > 5

ENTER CREW DAY IN HOURS (XX.X) > 12.

ENTER TIME OF DAY FOR AVERAGE AIRBASE TEMPERATURE (HH:MM) > 13:ØØ

LOWER PS BOUND FOR TAKEOFF ASAP.  NOTE THAT LOADING AND TAKEOFF WILL
ALWAYS OCCUR ASAP IF A VALUE OF 1.Ø IS ENTERED. ALSO NOTE THAT AN
AIRBASE CAN NOT BE A HOME BASE IF ITS 24 HOUR AIRCRAFT GROUND
SURVIVABILITY IS LESS THAN THE VALUE ENTERED HERE (OR IT DOES NOT HAVE
FUEL).

ENTER VALUE(.XX) > .998

WHEN TAKEOFF IS ASAP, A FACTOR CAN BE ENTERED TO
DECREASE NORMAL SERVICE, LOAD AND UNLOAD TIMES.

ENTER FACTOR (.XX) > 1.Ø

WHEN TAKEOFF IS ASAP, A FACTOR CAN ALSO BE ENTERED TO
DECREASE MISSION ESSENTIAL MAINTENANCE TIME.

ENTER FACTOR (.XX) > .5

AIRCRAFT SCHEDULING BY HIGH PS OR HIGH INPUT(P/I)? I

C13ØH FLIGHT SCHEDULE PRIORITY(X.X) > 2.

NORMALLY FLIGHTS TO DESTINATION AIRBASES ARE SELECTED AS A FUNCTION OF
BACKLOGGED CARGO WEIGHT.  ONCE SELECTED, AIRCRAFT ARE LOADED AS A
FUNCTION OF JOB PRIORITY.

IS THIS SCHEDULING APPROACH SATISFACTORY(Y/N)? N
```

```
NORMAL SCHEDULING AND RELOCATION WILL BE BYPASSED FOR JOBS HAVING A
PRIORITY HIGHER THAN OR EQUAL TO THE NUMBER SELECTED
(SMALLER OR EQUAL IN NUMERICAL VALUE).
ENTER PRIORITY NUMBER (XX) > 4

PS RESTRICTED SCHEDULING(Y/N)? N

INDIVIDUAL AIRLIFT JOBS PRINTOUT(Y/N)? N

SCENARIO STRUCTURE PRINTOUT(Y/N)? N

PROGRAM MODIFIED SCENARIO STRUCTURE PRINTOUT(Y/N)? N

AIRBASE CHARACTERISTICS PRINTOUT(Y/N)? N

AIRLIFTER CHARACTERISTICS PRINTOUT(Y/N)? N

OPERATIONAL PARAMETERS PRINTOUT(Y/N)? N

USE WT & VOL LOAD MODULE(Y/N)? Y

NOTE!  ALL NON-STANDARD JOBS MUST BE DIMENSIONED FOR
THIS MODE.  SINCE THE WT AND VOL LOADING MODULE REQUIRES
SOME CPU TIME TO ACCOMPLISH AIRLIFTER LOADING, SLIGHTLY
MORE CPU TIME WILL BE REQUIRED TO RUN IN THIS MODE.

THE PROGRAM COMPARES THE BELOW INPUT VALUE (TONS) TIMES AIRBASE MOG TO
THE TOTAL IN-BOUND PLUS BACKLOGGED JOBS AT AN AIRBASE AND STEP-WISE
SCHEDULES MOVEMENTS TO AIRBASES IN ORDER TO UNIFORMLY DISTRIBUTE JOBS AS
A FUNCTION OF AIRBASE MOG (THE SMALLER THE INPUT VALUE, THE MORE UNIFORM
THE DISTRIBUTION). A VALUE LESS THAN 3 TONS IS SET TO 3 TONS.

ENTER VALUE IN TONS (XXXXX) > 25

MEAN TIME (DAYS) TO ELIMINATE BLOCKED AIRCRAFT(XX.X) > 2.

ENTER MINIMUM SPOTS FOR TRANSIT AIRCRAFT(XX.) > 2.2

SEED FOR PK CALCULATIONS (DEFAULT)? <CR>

SEED FOR OTHER CALCULATIONS (DEFAULT)? <CR>

IMMEDIATE TAKEOFF WITH RELOCATION AUTHORIZED(Y/N)? Y

GENERALIZED SUMMARY DATA IS ALWAYS SAVED
ENTER ID OF FILE > RUNØ3OUT.LIS

STANDBY - INITIALIZING SIMULATION PARAMETERS

                              SIMULATION TIME = DAY  1
```

Appendix D: Design Matrices for Interaction Terms

Table 13A. Two–Factor Interaction Design Matrix

Test Condition Number	Run No	AF	AC	AI	AG	AS	FC	FI	FG	FS	CI	CG	CS	IG	IS	GS
1	EXP 19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	EXP 51	−	−	−	−	−	+	+	+	+	+	+	+	+	+	+
3	EXP 03	−	+	+	+	+	−	−	−	−	+	+	+	+	+	+
4	EXP 35	+	−	−	−	−	−	−	−	−	+	+	+	+	+	+
5	EXP 27	+	−	+	+	+	−	+	+	+	−	−	−	+	+	+
6	EXP 59	−	+	−	−	−	−	+	+	+	−	−	−	+	+	+
7	EXP 11	−	−	+	+	+	+	−	−	−	−	−	−	+	+	+
8	EXP 43	+	+	−	−	−	+	−	−	−	−	−	−	+	+	+
9	EXP 23	+	+	−	+	+	+	−	+	+	−	+	+	−	−	+
10	EXP 55	−	−	+	−	−	+	−	+	+	−	+	+	−	−	+
11	EXP 07	−	+	−	+	+	−	+	−	−	−	+	+	−	−	+
12	EXP 39	+	−	+	−	−	−	+	−	−	−	+	+	−	−	+
13	EXP 31	+	−	−	+	+	−	−	+	+	+	−	−	−	−	+
14	EXP 63	−	+	+	−	−	−	−	+	+	+	−	−	−	−	+
15	EXP 15	−	−	−	+	+	+	+	−	−	+	−	−	−	−	+
16	EXP 47	+	+	+	−	−	+	+	−	−	+	−	−	−	−	+
17	EXP 17	+	+	+	−	+	+	+	−	+	+	−	+	−	+	−
18	EXP 49	−	−	−	+	−	+	+	−	+	+	−	+	−	+	−
19	EXP 01	−	+	+	−	+	−	−	+	−	+	−	+	−	+	−
20	EXP 33	+	−	−	+	−	−	−	+	−	+	−	+	−	+	−
21	EXP 25	+	−	+	−	+	−	+	−	+	−	+	−	−	+	−
22	EXP 57	−	+	−	+	−	−	+	−	+	−	+	−	−	+	−
23	EXP 09	−	−	+	−	+	+	−	+	−	−	+	−	−	+	−
24	EXP 41	+	+	−	+	−	+	−	+	−	−	+	−	−	+	−
25	EXP 21	+	+	−	−	+	+	−	−	+	−	−	+	+	−	−
26	EXP 53	−	−	+	+	−	+	−	−	+	−	−	+	+	−	−
27	EXP 05	−	+	−	−	+	−	+	+	−	−	−	+	+	−	−
28	EXP 37	+	−	+	+	−	−	+	+	−	−	−	+	+	−	−
29	EXP 29	+	−	−	−	+	−	−	−	+	+	+	−	+	−	−
30	EXP 61	−	+	+	+	−	−	−	−	+	+	+	−	+	−	−
31	EXP 13	−	−	−	−	+	+	+	+	−	+	+	−	+	−	−
32	EXP 45	+	+	+	+	−	+	+	+	−	+	+	−	+	−	−

Table 13B. Two–Factor Interaction Design Matrix

Test Condition Number	Run No	AF	AC	AI	AG	AS	FC	FI	FG	FS	CI	CG	CS	IG	IS	GS
33	EXP 18	+	+	+	+	–	+	+	+	–	+	+	–	+	–	–
34	EXP 50	–	–	–	–	+	+	+	+	–	+	+	–	+	–	–
35	EXP 02	–	+	+	+	–	–	–	–	+	+	+	–	+	–	–
36	EXP 34	+	–	–	–	+	–	–	–	+	+	+	–	+	–	–
37	EXP 26	+	–	+	+	–	–	+	+	–	–	–	+	+	–	–
38	EXP 58	–	+	–	–	+	–	+	+	–	–	–	+	+	–	–
39	EXP 10	–	–	+	+	–	+	–	–	+	–	–	+	+	–	–
40	EXP 42	+	+	–	–	+	+	–	–	+	–	–	+	+	–	–
41	EXP 22	+	+	–	+	–	+	–	+	–	–	+	–	–	+	–
42	EXP 54	–	–	+	–	+	+	–	+	–	–	+	–	–	+	–
43	EXP 06	–	+	–	+	–	–	+	–	+	–	+	–	–	+	–
44	EXP 38	+	–	+	–	+	–	+	–	+	–	+	–	–	+	–
45	EXP 30	+	–	–	+	–	–	–	+	–	+	–	+	–	+	–
46	EXP 62	–	+	+	–	+	–	–	+	–	+	–	+	–	+	–
47	EXP 14	–	–	–	+	–	+	+	–	+	+	–	+	–	+	–
48	EXP 46	+	+	+	–	+	+	+	–	+	+	–	+	–	+	–
49	EXP 16	+	+	+	–	–	+	+	–	–	+	–	–	–	–	+
50	EXP 48	–	–	–	+	+	+	+	–	–	+	–	–	–	–	+
51	EXP 00	–	+	+	–	–	–	–	+	+	+	–	–	–	–	+
52	EXP 32	+	–	–	+	+	–	–	+	+	+	–	–	–	–	+
53	EXP 24	+	–	+	–	–	–	+	–	–	–	+	+	–	–	+
54	EXP 56	–	+	–	+	+	–	+	–	–	–	+	+	–	–	+
55	EXP 08	–	–	+	–	–	+	–	+	+	–	+	+	–	–	+
56	EXP 40	+	+	–	+	+	+	–	+	+	–	+	+	–	–	+
57	EXP 20	+	+	–	–	–	+	–	–	–	–	–	–	+	+	+
58	EXP 52	–	–	+	+	+	+	–	–	–	–	–	–	+	+	+
59	EXP 04	–	+	–	–	–	–	+	+	+	–	–	–	+	+	+
60	EXP 36	+	–	+	+	+	–	+	+	+	–	–	–	+	+	+
61	EXP 28	+	–	–	–	–	–	–	–	–	+	+	+	+	+	+
62	EXP 60	–	+	+	+	+	–	–	–	–	+	+	+	+	+	+
63	EXP 12	–	–	–	–	–	+	+	+	+	+	+	+	+	+	+
64	EXP 44	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 14A. Three-Factor Interaction Design Matrix

Test Condition Number	Run No	AFC	AFI	AFG	AFS	ACI	ACG	ACS	AIG	AIS	AGS	FCI	FCG	FCS	FIG	FIS	FGS	CIG	CIS	CGS	IGS
1	EXP 19	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
2	EXP 51	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−
3	EXP 03	+	+	+	+	−	−	−	−	−	−	+	+	+	+	+	+	−	−	−	−
4	EXP 35	−	−	−	−	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−
5	EXP 27	+	−	−	−	+	+	+	−	−	−	+	+	+	−	−	−	+	+	+	−
6	EXP 59	−	+	+	+	−	−	−	+	+	+	+	+	+	−	−	−	+	+	+	−
7	EXP 11	−	+	+	+	+	+	+	−	−	−	−	−	−	+	+	+	+	+	+	−
8	EXP 43	+	−	−	−	−	−	−	+	+	+	−	−	−	+	+	+	+	+	+	−
9	EXP 23	−	+	−	−	+	−	−	+	+	−	+	−	−	+	+	−	+	+	−	+
10	EXP 55	+	−	+	+	−	+	+	−	−	+	+	−	−	+	+	−	+	+	−	+
11	EXP 07	+	−	+	+	+	−	−	+	+	−	−	+	+	−	−	+	+	+	−	+
12	EXP 39	−	+	−	−	−	+	+	−	−	+	−	+	+	−	−	+	+	+	−	+
13	EXP 31	+	+	−	−	−	+	+	+	+	−	−	+	+	+	+	−	−	−	+	+
14	EXP 63	−	−	+	+	+	−	−	−	−	+	−	+	+	+	+	−	−	−	+	+
15	EXP 15	−	−	+	+	−	+	+	+	+	−	+	−	−	−	−	+	−	−	+	+
16	EXP 47	+	+	−	−	+	−	−	−	−	+	+	−	−	−	−	+	−	−	+	+
17	EXP 17	−	−	+	−	−	+	−	+	−	+	−	+	−	+	−	+	+	−	+	+
18	EXP 49	+	+	−	+	+	−	+	−	+	−	−	+	−	+	−	+	+	−	+	+
19	EXP 01	+	+	−	+	−	+	−	+	−	+	+	−	+	−	+	−	+	−	+	+
20	EXP 33	−	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	+
21	EXP 25	+	−	+	−	+	−	+	+	−	+	+	−	+	+	−	+	−	+	−	+
22	EXP 57	−	+	−	+	−	+	−	−	+	−	+	−	+	+	−	+	−	+	−	+
23	EXP 09	−	+	−	+	+	−	+	+	−	+	−	+	−	−	+	−	−	+	−	+
24	EXP 41	+	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	+
25	EXP 21	−	+	+	−	+	+	−	−	+	+	+	+	−	−	+	+	−	+	+	−
26	EXP 53	+	−	−	+	−	−	+	+	−	−	+	+	−	−	+	+	−	+	+	−
27	EXP 05	+	−	−	+	+	+	−	−	+	+	−	−	+	+	−	−	−	+	+	−
28	EXP 37	−	+	+	−	−	−	+	+	−	−	−	−	+	+	−	−	−	+	+	−
29	EXP 29	+	+	+	−	−	−	+	−	+	+	−	−	+	−	+	+	+	−	−	−
30	EXP 61	−	−	−	+	+	+	−	+	−	−	−	−	+	−	+	+	+	−	−	−
31	EXP 13	−	−	−	+	−	−	+	−	+	+	+	+	−	+	−	−	+	−	−	−
32	EXP 45	+	+	+	−	+	+	−	+	−	−	+	+	−	+	−	−	+	−	−	−

Table 14B. Three-Factor Interaction Design Matrix

Test Condition Number	Run No	AFC	AFI	AFG	AFS	ACI	ACG	ACS	AIG	AIS	AGS	FCI	FCG	FCS	FIG	FIS	FGS	CIG	CIS	CGS	IGS
33	EXP 18	−	−	−	+	−	−	+	−	+	+	−	−	+	−	+	+	−	+	+	+
34	EXP 50	+	+	+	−	+	+	−	+	−	−	−	−	+	−	+	+	−	+	+	+
35	EXP 02	+	+	+	−	−	−	+	−	+	+	+	+	−	+	−	−	−	+	+	+
36	EXP 34	−	−	−	+	+	+	−	+	−	−	+	+	−	+	−	−	−	+	+	+
37	EXP 26	+	−	−	+	+	+	−	−	+	+	+	+	−	−	+	+	+	−	−	+
38	EXP 58	−	+	+	−	−	−	+	+	−	−	+	+	−	−	+	+	+	−	−	+
39	EXP 10	−	+	+	−	+	+	−	−	+	+	−	−	+	+	−	−	+	−	−	+
40	EXP 42	+	−	−	+	−	−	+	+	−	−	−	−	+	+	−	−	+	−	−	+
41	EXP 22	−	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	−
42	EXP 54	+	−	+	−	−	+	−	−	+	−	+	−	+	+	−	+	+	−	+	−
43	EXP 06	+	−	+	−	+	−	+	+	−	+	−	+	−	−	+	−	+	−	+	−
44	EXP 38	−	+	−	+	−	+	−	−	+	−	−	+	−	−	+	−	+	−	+	−
45	EXP 30	+	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	−
46	EXP 62	−	−	+	−	+	−	+	−	+	−	−	+	−	+	−	+	−	+	−	−
47	EXP 14	−	−	+	−	−	+	−	+	−	+	+	−	+	−	+	−	−	+	−	−
48	EXP 46	+	+	−	+	+	−	+	−	+	−	+	−	+	−	+	−	−	+	−	−
49	EXP 16	−	−	+	+	−	+	+	+	+	−	−	+	+	+	+	−	+	+	−	−
50	EXP 48	+	+	−	−	+	−	−	−	−	+	−	+	+	+	+	−	+	+	−	−
51	EXP 00	+	+	−	−	−	+	+	+	+	−	+	−	−	−	−	+	+	+	−	−
52	EXP 32	−	−	+	+	+	−	−	−	−	+	+	−	−	−	−	+	+	+	−	−
53	EXP 24	+	−	+	+	+	−	−	+	+	−	+	−	−	+	+	−	−	−	+	−
54	EXP 56	−	+	−	−	−	+	+	−	−	+	+	−	−	+	+	−	−	−	+	−
55	EXP 08	−	+	−	−	+	−	−	+	+	−	−	+	+	−	−	+	−	−	+	−
56	EXP 40	+	−	+	+	−	+	+	−	−	+	−	+	+	−	−	+	−	−	+	−
57	EXP 20	−	+	+	+	+	+	+	−	−	−	+	+	+	−	−	−	−	−	−	+
58	EXP 52	+	−	−	−	−	−	−	+	+	+	+	+	+	−	−	−	−	−	−	+
59	EXP 04	+	−	−	−	+	+	+	−	−	−	−	−	−	+	+	+	−	−	−	+
60	EXP 36	−	+	+	+	−	−	−	+	+	+	−	−	−	+	+	+	−	−	−	+
61	EXP 28	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+
62	EXP 60	−	−	−	−	+	+	+	+	+	+	−	−	−	−	−	−	+	+	+	+
63	EXP 12	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	+
64	EXP 44	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 15A Four-Factor Interaction Design Matrix

Test Condition Number	Run No	AFCI	AFCG	AFCS	AFIG	AFIS	AFGS	ACIG	ACIS	ACGS	AIGS	FCIG	FCIS	FCGS	FIGS	CIGS
1	EXP 19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	EXP 51	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
3	EXP 03	-	-	-	-	-	-	+	+	+	+	-	-	-	-	+
4	EXP 35	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+
5	EXP 27	-	-	-	+	+	+	-	-	-	+	-	-	-	+	-
6	EXP 59	+	+	+	-	-	-	+	+	+	-	-	-	-	+	-
7	EXP 11	+	+	+	-	-	-	-	-	-	+	+	+	+	-	-
8	EXP 43	-	-	-	+	+	+	+	+	+	-	+	+	+	-	-
9	EXP 23	-	+	+	-	-	+	-	-	+	-	-	-	+	-	-
10	EXP 55	+	-	-	+	+	-	+	+	-	+	-	-	+	-	-
11	EXP 07	+	-	-	+	+	-	-	-	+	-	+	+	-	+	-
12	EXP 39	-	+	+	-	-	+	+	+	-	+	+	+	-	+	-
13	EXP 31	+	-	-	-	-	+	+	+	-	-	+	+	-	-	+
14	EXP 63	-	+	+	+	+	-	-	-	+	+	+	+	-	-	+
15	EXP 15	-	+	+	+	+	-	+	+	-	-	-	-	+	+	+
16	EXP 47	+	-	-	-	-	+	-	-	+	+	-	-	+	+	+
17	EXP 17	+	-	+	-	+	-	-	+	-	-	-	+	-	-	-
18	EXP 49	-	+	-	+	-	+	+	-	+	+	-	+	-	-	-
19	EXP 01	-	+	-	+	-	+	-	+	-	-	+	-	+	+	-
20	EXP 33	+	-	+	-	+	-	+	-	+	+	+	-	+	+	-
21	EXP 25	-	+	-	-	+	-	+	-	+	-	+	-	+	-	+
22	EXP 57	+	-	+	+	-	+	-	+	-	+	+	-	+	-	+
23	EXP 09	+	-	+	+	-	+	+	-	+	-	-	+	-	+	+
24	EXP 41	-	+	-	-	+	-	-	+	-	+	-	+	-	+	+
25	EXP 21	-	-	+	+	-	-	+	-	-	+	+	-	-	+	+
26	EXP 53	+	+	-	-	+	+	-	+	+	-	+	-	-	+	+
27	EXP 05	+	+	-	-	+	+	+	-	-	+	-	+	+	-	+
28	EXP 37	-	-	+	+	-	-	-	+	+	-	-	+	+	-	+
29	EXP 29	+	+	-	+	-	-	-	+	+	+	-	+	+	+	-
30	EXP 61	-	-	+	-	+	+	+	-	-	-	-	+	+	+	-
31	EXP 13	-	-	+	-	+	+	-	+	+	+	+	-	-	-	-
32	EXP 45	+	+	-	+	-	-	+	-	-	-	+	-	-	-	-

Table 15B. Four-Factor Interaction Design Matrix

Test Condition Number	Run No	AFCI	AFCG	AFCS	AFIG	AFIS	AFGS	ACIG	ACIS	ACGS	AIGS	FCIG	FCIS	FCGS	FIGS	CIGS
33	EXP 18	+	+	-	+	-	-	+	-	-	-	+	-	-	-	-
34	EXP 50	-	-	+	-	+	+	-	+	+	+	+	-	-	-	-
35	EXP 02	-	-	+	-	+	+	+	-	-	-	-	+	+	+	-
36	EXP 34	+	+	-	+	-	-	-	+	+	+	-	+	+	+	-
37	EXP 26	-	-	+	+	-	-	-	+	+	-	-	+	+	-	+
38	EXP 58	+	+	-	-	+	+	+	-	-	+	-	+	+	-	+
39	EXP 10	+	+	-	-	+	+	-	+	+	-	+	-	-	+	+
40	EXP 42	-	-	+	+	-	-	+	-	-	+	+	-	-	+	+
41	EXP 22	-	+	-	-	+	-	-	+	-	+	-	+	-	+	+
42	EXP 54	+	-	+	+	-	+	+	-	+	-	-	+	-	+	+
43	EXP 06	+	-	+	+	-	+	-	+	-	+	+	-	+	-	+
44	EXP 38	-	+	-	-	+	-	+	-	+	-	+	-	+	-	+
45	EXP 30	+	-	+	-	+	-	+	-	+	+	+	-	+	+	-
46	EXP 62	-	+	-	+	-	+	-	+	-	-	+	-	+	+	-
47	EXP 14	-	+	-	+	-	+	+	-	+	+	-	+	-	-	-
48	EXP 46	+	-	+	-	+	-	-	+	-	-	-	+	-	-	-
49	EXP 16	+	-	-	-	-	+	-	-	+	+	-	-	+	+	+
50	EXP 48	-	+	+	+	+	-	+	+	-	-	-	-	+	+	+
51	EXP 00	-	+	+	+	+	-	-	-	+	+	+	+	-	-	+
52	EXP 32	+	-	-	-	-	+	+	+	-	-	+	+	-	-	+
53	EXP 24	-	+	+	-	-	+	+	+	-	+	+	+	-	+	-
54	EXP 56	+	-	-	+	+	-	-	-	+	-	+	+	-	+	-
55	EXP 08	+	-	-	+	+	-	+	+	-	+	-	-	+	-	-
56	EXP 40	-	+	+	-	-	+	-	-	+	-	-	-	+	-	-
57	EXP 20	-	-	-	+	+	+	+	+	+	-	+	+	+	-	-
58	EXP 52	+	+	+	-	-	-	-	-	-	+	+	+	+	-	-
59	EXP 04	+	+	+	-	-	-	+	+	+	-	-	-	-	+	-
60	EXP 36	-	-	-	+	+	+	-	-	-	+	-	-	-	+	-
61	EXP 28	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+
62	EXP 60	-	-	-	-	-	-	+	+	+	+	-	-	-	-	+
63	EXP 12	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
64	EXP 44	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table 16A. Five-Factor and Six-Factor Interaction Design Matrices

Test Condition Number	Run No	AFCIG	AFCIS	AFCGS	AFIGS	ACIGS	FCIGS
1	EXP 19	–	–	–	–	–	–
2	EXP 51	+	+	+	+	+	–
3	EXP 03	+	+	+	+	–	+
4	EXP 35	–	–	–	–	+	+
5	EXP 27	+	+	+	–	+	+
6	EXP 59	–	–	–	+	–	+
7	EXP 11	–	–	–	+	+	–
8	EXP 43	+	+	+	–	–	–
9	EXP 23	+	+	–	+	+	+
10	EXP 55	–	–	+	–	–	+
11	EXP 07	–	–	+	–	+	–
12	EXP 39	+	+	–	+	–	–
13	EXP 31	–	–	+	+	–	–
14	EXP 63	+	+	–	–	+	–
15	EXP 15	+	+	–	–	–	+
16	EXP 47	–	–	+	+	+	+
17	EXP 17	+	–	+	+	+	+
18	EXP 49	–	+	–	–	–	+
19	EXP 01	–	+	–	–	+	–
20	EXP 33	+	–	+	+	–	–
21	EXP 25	–	+	–	+	–	–
22	EXP 57	+	–	+	–	+	–
23	EXP 09	+	–	+	–	–	+
24	EXP 41	–	+	–	+	+	+
25	EXP 21	–	+	+	–	–	–
26	EXP 53	+	–	–	+	+	–
27	EXP 05	+	–	–	+	–	+
28	EXP 37	–	+	+	–	+	+
29	EXP 29	+	–	–	–	+	+
30	EXP 61	–	+	+	+	–	+
31	EXP 13	–	+	+	+	+	–
32	EXP 45	+	–	–	–	–	–

Test Condition Number	Run No	AFCIGS
1	EXP 19	+
2	EXP 51	–
3	EXP 03	–
4	EXP 35	+
5	EXP 27	–
6	EXP 59	+
7	EXP 11	+
8	EXP 43	–
9	EXP 23	–
10	EXP 55	+
11	EXP 07	+
12	EXP 39	–
13	EXP 31	+
14	EXP 63	–
15	EXP 15	–
16	EXP 47	+
17	EXP 17	–
18	EXP 49	+
19	EXP 01	+
20	EXP 33	–
21	EXP 25	+
22	EXP 57	–
23	EXP 09	–
24	EXP 41	+
25	EXP 21	+
26	EXP 53	–
27	EXP 05	–
28	EXP 37	+
29	EXP 29	–
30	EXP 61	+
31	EXP 13	+
32	EXP 45	–

Table 16B. Five-Factor and Six-Factor Interaction Design Matrices

Test Condition Number	Run No	AFCIG	AFCIS	AFCGS	AFIGS	ACIGS	FCIGS
33	EXP 18	–	+	+	+	+	+
34	EXP 50	+	–	–	–	–	+
35	EXP 02	+	–	–	–	+	–
36	EXP 34	–	+	+	+	–	–
37	EXP 26	+	–	–	+	–	–
38	EXP 58	–	+	+	–	+	–
39	EXP 10	–	+	+	–	–	+
40	EXP 42	+	–	–	+	+	+
41	EXP 22	+	–	+	–	–	–
42	EXP 54	–	+	–	+	+	–
43	EXP 06	–	+	–	+	–	+
44	EXP 38	+	–	+	–	+	+
45	EXP 30	–	+	–	–	+	+
46	EXP 62	+	–	+	+	–	+
47	EXP 14	+	–	+	+	+	–
48	EXP 46	–	+	–	–	–	–
49	EXP 16	+	+	–	–	–	–
50	EXP 48	–	–	+	+	+	–
51	EXP 00	–	–	+	+	–	+
52	EXP 32	+	+	–	–	+	+
53	EXP 24	–	–	+	–	+	+
54	EXP 56	+	+	–	+	–	+
55	EXP 08	+	+	–	+	+	–
56	EXP 40	–	–	+	–	–	–
57	EXP 20	–	–	–	+	+	+
58	EXP 52	+	+	+	–	–	+
59	EXP 04	+	+	+	–	+	–
60	EXP 36	–	–	–	+	–	–
61	EXP 28	+	+	+	+	–	–
62	EXP 60	–	–	–	–	+	–
63	EXP 12	–	–	–	–	–	+
64	EXP 44	+	+	+	+	+	+

Test Condition Number	Run No	AFCIGS
33	EXP 18	–
34	EXP 50	+
35	EXP 02	+
36	EXP 34	–
37	EXP 26	+
38	EXP 58	–
39	EXP 10	–
40	EXP 42	+
41	EXP 22	+
42	EXP 54	–
43	EXP 06	–
44	EXP 38	+
45	EXP 30	–
46	EXP 62	+
47	EXP 14	+
48	EXP 46	–
49	EXP 16	+
50	EXP 48	–
51	EXP 00	–
52	EXP 32	+
53	EXP 24	–
54	EXP 56	+
55	EXP 08	+
56	EXP 40	–
57	EXP 20	–
58	EXP 52	+
59	EXP 04	+
60	EXP 36	–
61	EXP 28	+
62	EXP 60	–
63	EXP 12	–
64	EXP 44	+

Appendix E: Results and Calculations for the Number of Required Replications

Table 17. Calculation of Number of Runs Required - One Percent Accuracy

NUMBER OF CUMULATIVE RUNS		TONS ON TIME	NUMBER OF RUNS REQUIRED	TONS DELIVERED	NUMBER OF RUNS REQUIRED	TOTAL FLIGHT HOURS	NUMBER OF RUNS REQUIRED
2	MEAN	2141.00		5833.00		4035.00	
2	STDS	24.04	201.46	104.65	523.67	19.80	38.60
3	MEAN	2152.33		5796.33		4047.67	
3	STDS	25.97	26.96	97.52	52.15	26.03	7.65
4	MEAN	2152.25		5797.50		4045.75	
4	STDS	21.20	9.83	79.66	19.03	21.59	2.88
5	MEAN	2155.20		5795.00		4035.20	
5	STDS	19.51	6.33	69.21	10.93	30.10	4.26
6	MEAN	2146.67		5794.50		4047.17	
6	STDS	27.23	10.58	61.92	7.50	39.80	6.39
7	MEAN	2151.86		5799.57		4040.29	
7	STDS	28.40	10.43	58.09	5.98	40.64	6.03
8	MEAN	2152.75		5810.63		4042.88	
8	STDS	26.41	8.42	62.21	6.41	38.33	5.01
9	MEAN	2153.33		5808.78		4047.33	
9	STDS	24.77	7.04	58.45	5.38	38.27	4.75
10	MEAN	2152.20		5810.70		4049.20	
10	STDS	23.63	6.17	55.45	4.66	36.56	4.17
	e = 1%	21.522		58.107		40.492	

NUMBER OF CUMULATIVE RUNS		TOTAL SORTIES	NUMBER OF RUNS REQUIRED	PRODUCTIVE FLIGHT HOURS	NUMBER OF RUNS REQUIRED	PRODUCTIVE SORTIES	NUMBER OF RUNS REQUIRED
2	MEAN	7292.50		463.50		855.00	
2	STDS	2.12	0.14	4.95	185.95	14.14	443.14
3	MEAN	7337.00		458.00		847.00	
3	STDS	77.09	20.62	10.15	89.66	17.09	74.20
4	MEAN	7329.00		457.00		847.00	
4	STDS	64.95	8.00	8.52	34.59	13.95	27.05
5	MEAN	7308.40		459.00		850.20	
5	STDS	72.70	7.63	8.63	26.99	14.04	20.86
6	MEAN	7328.83		457.33		847.67	
6	STDS	82.06	8.34	8.73	23.70	14.01	17.80
7	MEAN	7308.14		458.00		848.14	
7	STDS	92.78	9.66	8.16	18.77	12.85	13.57
8	MEAN	7305.75		459.75		851.13	
8	STDS	86.16	7.78	9.04	21.47	14.58	16.33
9	MEAN	7304.00		460.56		852.67	
9	STDS	80.77	6.50	8.79	19.32	14.40	15.14
10	MEAN	7304.80		461.20		853.60	
10	STDS	76.19	5.57	8.53	17.52	13.90	13.56
	e = 1%	73.048		4.612		8.536	

a =(1-0.95)				
n =	2	3	4	5
t(a/2, n-1)=	12.706	4.303	3.182	2.776
6	7	8	9	10
2.571	2.447	2.365	2.306	2.262

Table 18. Calculation of Number of Runs Required - Two Percent Accuracy

NUMBER OF CUMULATIVE RUNS		TONS ON TIME	NUMBER OF RUNS REQUIRED	TONS DELIVERED	NUMBER OF RUNS REQUIRED	TOTAL FLIGHT HOURS	NUMBER OF RUNS REQUIRED
2	MEAN	2141.00		5833.00		4035.00	
2	STDS	24.04	50.36	104.65	130.92	19.80	9.65
3	MEAN	2152.33		5796.33		4047.67	
3	STDS	25.97	6.74	97.52	13.04	26.03	1.91
4	MEAN	2152.25		5797.50		4045.75	
4	STDS	21.20	2.46	79.66	4.76	21.59	0.72
5	MEAN	2155.20		5795.00		4035.20	
5	STDS	19.51	1.58	69.21	2.73	30.10	1.06
6	MEAN	2146.67		5794.50		4047.17	
6	STDS	27.23	2.65	61.92	1.88	39.80	1.60
7	MEAN	2151.86		5799.57		4040.29	
7	STDS	28.40	2.61	58.09	1.50	40.64	1.51
8	MEAN	2152.75		5810.63		4042.88	
8	STDS	26.41	2.11	62.21	1.60	38.33	1.25
9	MEAN	2153.33		5808.78		4047.33	
9	STDS	24.77	1.76	58.45	1.35	38.27	1.19
10	MEAN	2152.20		5810.70		4049.20	
10	STDS	23.63	1.54	55.45	1.16	36.56	1.04

e = 2%	43.044	116.214	80.984

NUMBER OF CUMULATIVE RUNS		TOTAL SORTIES	NUMBER OF RUNS REQUIRED	PRODUCTIVE FLIGHT HOURS	NUMBER OF RUNS REQUIRED	PRODUCTIVE SORTIES	NUMBER OF RUNS REQUIRED
2	MEAN	7292.50		463.50		855.00	
2	STDS	2.12	0.03	4.95	46.49	14.14	110.78
3	MEAN	7337.00		458.00		847.00	
3	STDS	77.09	5.16	10.15	22.42	17.09	18.55
4	MEAN	7329.00		457.00		847.00	
4	STDS	64.95	2.00	8.52	8.65	13.95	6.76
5	MEAN	7308.40		459.00		850.20	
5	STDS	72.70	1.91	8.63	6.75	14.04	5.21
6	MEAN	7328.83		457.33		847.67	
6	STDS	82.06	2.09	8.73	5.93	14.01	4.45
7	MEAN	7308.14		458.00		848.14	
7	STDS	92.78	2.41	8.16	4.69	12.85	3.39
8	MEAN	7305.75		459.75		851.13	
8	STDS	86.16	1.95	9.04	5.37	14.58	4.08
9	MEAN	7304.00		460.56		852.67	
9	STDS	80.77	1.63	8.79	4.83	14.40	3.79
10	MEAN	7304.80		461.20		853.60	
10	STDS	76.19	1.39	8.53	4.38	13.90	3.39

e = 2%	146.096		9.224		17.072	
a =(1-0.95)						
n =	2	3	4	5		
t(a/2, n-1)=	12.706	4.303	3.182	2.776		
6	7	8	9	10		
2.571	2.447	2.365	2.306	2.262		

Table 19. Calculation of Number of Runs Required - Three Percent Accuracy

NUMBER OF CUMULATIVE RUNS		TONS ON TIME	NUMBER OF RUNS REQUIRED	TONS DELIVERED	NUMBER OF RUNS REQUIRED	TOTAL FLIGHT HOURS	NUMBER OF RUNS REQUIRED
2	MEAN	2141.00		5833.00		4035.00	
2	STDS	24.04	22.38	104.65	58.19	19.80	4.29
3	MEAN	2152.33		5796.33		4047.67	
3	STDS	25.97	3.00	97.52	5.79	26.03	0.85
4	MEAN	2152.25		5797.50		4045.75	
4	STDS	21.20	1.09	79.66	2.11	21.59	0.32
5	MEAN	2155.20		5795.00		4035.20	
5	STDS	19.51	0.70	69.21	1.21	30.10	0.47
6	MEAN	2146.67		5794.50		4047.17	
6	STDS	27.23	1.18	61.92	0.83	39.80	0.71
7	MEAN	2151.86		5799.57		4040.29	
7	STDS	28.40	1.16	58.09	0.66	40.64	0.67
8	MEAN	2152.75		5810.63		4042.88	
8	STDS	26.41	0.94	62.21	0.71	38.33	0.56
9	MEAN	2153.33		5808.78		4047.33	
9	STDS	24.77	0.78	58.45	0.60	38.27	0.53
10	MEAN	2152.20		5810.70		4049.20	
10	STDS	23.63	0.69	55.45	0.52	36.56	0.46

e = 3%   64.566   174.321   121.476

NUMBER OF CUMULATIVE RUNS		TOTAL SORTIES	NUMBER OF RUNS REQUIRED	PRODUCTIVE FLIGHT HOURS	NUMBER OF RUNS REQUIRED	PRODUCTIVE SORTIES	NUMBER OF RUNS REQUIRED
2	MEAN	7292.50		463.50		855.00	
2	STDS	2.12	0.02	4.95	20.66	14.14	49.24
3	MEAN	7337.00		458.00		847.00	
3	STDS	77.09	2.29	10.15	9.96	17.09	8.24
4	MEAN	7329.00		457.00		847.00	
4	STDS	64.95	0.89	8.52	3.84	13.95	3.01
5	MEAN	7308.40		459.00		850.20	
5	STDS	72.70	0.85	8.63	3.00	14.04	2.32
6	MEAN	7328.83		457.33		847.67	
6	STDS	82.06	0.93	8.73	2.63	14.01	1.98
7	MEAN	7308.14		458.00		848.14	
7	STDS	92.78	1.07	8.16	2.09	12.85	1.51
8	MEAN	7305.75		459.75		851.13	
8	STDS	86.16	0.86	9.04	2.39	14.58	1.81
9	MEAN	7304.00		460.56		852.67	
9	STDS	80.77	0.72	8.79	2.15	14.40	1.68
10	MEAN	7304.80		461.20		853.60	
10	STDS	76.19	0.62	8.53	1.95	13.90	1.51

e = 3%   219.144   13.836   25.608

a =(1-0.95)

n =	2	3	4	5	
t(a/2, n-1)=	12.706	4.303	3.182	2.776	
6	7	8	9	10	
2.571	2.447	2.365	2.306	2.262	

Table 20. Calculation of Number of Runs Required - Four Percent Accuracy

NUMBER OF CUMULATIVE RUNS		TONS ON TIME	NUMBER OF RUNS REQUIRED	TONS DELIVERED	NUMBER OF RUNS REQUIRED	TOTAL FLIGHT HOURS	NUMBER OF RUNS REQUIRED
2	MEAN	2141.00		5833.00		4035.00	
2	STDS	24.04	12.59	104.65	32.73	19.80	2.41
3	MEAN	2152.33		5796.33		4047.67	
3	STDS	25.97	1.68	97.52	3.26	26.03	0.48
4	MEAN	2152.25		5797.50		4045.75	
4	STDS	21.20	0.61	79.66	1.19	21.59	0.18
5	MEAN	2155.20		5795.00		4035.20	
5	STDS	19.51	0.40	69.21	0.68	30.10	0.27
6	MEAN	2146.67		5794.50		4047.17	
6	STDS	27.23	0.66	61.92	0.47	39.80	0.40
7	MEAN	2151.86		5799.57		4040.29	
7	STDS	28.40	0.65	58.09	0.37	40.64	0.38
8	MEAN	2152.75		5810.63		4042.88	
8	STDS	26.41	0.53	62.21	0.40	38.33	0.31
9	MEAN	2153.33		5808.78		4047.33	
9	STDS	24.77	0.44	58.45	0.34	38.27	0.30
10	MEAN	2152.20		5810.70		4049.20	
10	STDS	23.63	0.39	55.45	0.29	36.56	0.26

e = 4%	86.088	232.428	161.968	

NUMBER OF CUMULATIVE RUNS		TOTAL SORTIES	NUMBER OF RUNS REQUIRED	PRODUCTIVE FLIGHT HOURS	NUMBER OF RUNS REQUIRED	PRODUCTIVE SORTIES	NUMBER OF RUNS REQUIRED
2	MEAN	7292.50		463.50		855.00	
2	STDS	2.12	0.01	4.95	11.62	14.14	27.70
3	MEAN	7337.00		458.00		847.00	
3	STDS	77.09	1.29	10.15	5.60	17.09	4.64
4	MEAN	7329.00		457.00		847.00	
4	STDS	64.95	0.50	8.52	2.16	13.95	1.69
5	MEAN	7308.40		459.00		850.20	
5	STDS	72.70	0.48	8.63	1.69	14.04	1.30
6	MEAN	7328.83		457.33		847.67	
6	STDS	82.06	0.52	8.73	1.48	14.01	1.11
7	MEAN	7308.14		458.00		848.14	
7	STDS	92.78	0.60	8.16	1.17	12.85	0.85
8	MEAN	7305.75		459.75		851.13	
8	STDS	86.16	0.49	9.04	1.34	14.58	1.02
9	MEAN	7304.00		460.56		852.67	
9	STDS	80.77	0.41	8.79	1.21	14.40	0.95
10	MEAN	7304.80		461.20		853.60	
10	STDS	76.19	0.35	8.53	1.10	13.90	0.85

e = 4%	292.192		18.448		34.144	
a = (1 -0.95)						
n =	2	3	4	5		
t(a/2, n-1)=	12.706	4.303	3.182	2.776		
6	7	8	9	10		
2.571	2.447	2.365	2.306	2.262		

Appendix F: Random Number Seeds Used For Experimental Runs

Run Number	Random Number Seeds PK	Random Number Seeds OTHER	Run Number	Random Number Seeds PK	Random Number Seeds OTHER
EXP 00	2006429302	600743814	EXP 32	2032429302	632743814
EXP 01	2016429302	601743814	EXP 33	2033429302	633743814
EXP 02	2026429302	602743814	EXP 34	2034429302	634743814
EXP 03	2036429302	603743814	EXP 35	2035429302	635743814
EXP 04	2046429302	604743814	EXP 36	2036429302	636743814
EXP 05	2056429302	605743814	EXP 37	2037429302	637743814
EXP 06	2066429302	606743814	EXP 38	2038429302	638743814
EXP 07	2076429302	607743814	EXP 39	2039429302	639743814
EXP 08	2086429302	608743814	EXP 40	2040429302	640743814
EXP 09	2096429302	609743814	EXP 41	2041429302	641743814
EXP 10	2106429302	610743814	EXP 42	2042429302	642743814
EXP 11	2116429302	611743814	EXP 43	2043429302	643743814
EXP 12	2126429302	612743814	EXP 44	2044429302	644743814
EXP 13	2136429302	613743814	EXP 45	2045429302	645743814
EXP 14	2146429302	614743814	EXP 46	2046429302	646743814
EXP 15	2115429302	615743814	EXP 47	2047429302	647743814
EXP 16	2016429302	616743814	EXP 48	2048429302	648743814
EXP 17	2017429302	617743814	EXP 49	2049429302	649743814
EXP 18	2018429302	618743814	EXP 50	2050429302	650743814
EXP 19	2019429302	619743814	EXP 51	2051429302	651743814
EXP 20	2020429302	620743814	EXP 52	2052429302	652743814
EXP 21	2021429302	621743814	EXP 53	2053429302	653743814
EXP 22	2022429302	622743814	EXP 54	2054429302	654743814
EXP 23	2023429302	623743814	EXP 55	2055429302	655743814
EXP 24	2024429302	624743814	EXP 56	2056429302	656743814
EXP 25	2025429302	625743814	EXP 57	2057429302	657743814
EXP 26	2026429302	626743814	EXP 58	2058429302	658743814
EXP 27	2027429302	627743814	EXP 59	2059429302	659743814
EXP 28	2028429302	628743814	EXP 60	2060429302	660743814
EXP 29	2029429302	629743814	EXP 61	2061429302	661743814
EXP 30	2030429302	630743814	EXP 62	2062429302	662743814
EXP 31	2031429302	631743814	EXP 63	2063429302	663743814

Table 21A. Yate's algorithm, Results for Ratio On Time

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio On Time	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	-	-	-	-	-	-	0.12	0.24	0.48	1.30	2.60	7.41	15.31	64	0.239219	average
2	EXP 51	+	-	-	-	-	-	0.12	0.24	0.82	1.30	4.81	7.90	0.65	32	0.020313	A
3	EXP 03	-	+	-	-	-	-	0.12	0.41	0.48	2.41	2.68	0.35	0.21	32	0.006563	F
4	EXP 35	+	+	-	-	-	-	0.12	0.41	0.82	2.40	5.22	0.30	0.11	32	0.003438	AF
5	EXP 27	-	-	+	-	-	-	0.19	0.24	0.79	1.36	0.12	0.07	4.99	32	0.155938	C
6	EXP 59	+	-	+	-	-	-	0.22	0.24	1.62	1.32	0.23	0.14	0.49	32	0.015313	AC
7	EXP 11	-	+	+	-	-	-	0.19	0.41	0.77	2.61	0.08	0.05	0.09	32	0.002813	FC
8	EXP 43	+	+	+	-	-	-	0.22	0.41	1.63	2.61	0.22	0.06	0.07	32	0.002187	AFC
9	EXP 23		-	-	+	-	-	0.12	0.39	0.48	0.06	0.00	2.37	-0.05	32	-0.001562	I
10	EXP 55	+	-	-	+	-	-	0.12	0.40	0.88	0.06	0.07	2.62	-0.07	32	-0.002188	AI
11	EXP 07	-	+	-	+	-	-	0.12	0.80	0.48	0.13	0.00	0.27	0.01	32	0.000313	FI
12	EXP 39	+	+	-	+	-	-	0.12	0.82	0.84	0.10	0.14	0.22	-0.01	32	-0.000313	AFI
13	EXP 31	-	-	+	+	-	-	0.19	0.38	0.86	0.04	0.00	0.03	0.07	32	0.002188	CI
14	EXP 63	+	-	+	+	-	-	0.22	0.39	1.75	0.04	0.05	0.06	0.05	32	0.001562	ACI
15	EXP 15	-	+	+	+	-	-	0.19	0.80	0.82	0.13	0.00	0.01	0.01	32	0.000313	FCI
16	EXP 47	+	+	+	+	-	-	0.22	0.83	1.79	0.09	0.06	0.06	-0.01	32	-0.000313	AFCI
17	EXP 17	-	-	-	-	+	-	0.19	0.24	0.00	0.00	0.68	-0.01	4.75	32	0.148438	G
18	EXP 49	+	-	-	-	+	-	0.2	0.24	0.06	0.00	1.69	-0.04	0.25	32	0.007813	AG
19	EXP 01	-	+	-	-	+	-	0.19	0.44	0.00	0.03	0.76	-0.03	0.21	32	0.006563	FG
20	EXP 33	+	+	-	-	+	-	0.21	0.44	0.06	0.04	1.86	-0.04	0.11	32	0.003438	AFG
21	EXP 25	-	-	+	-	+	-	0.38	0.24	0.03	0.00	0.12	0.01	2.11	32	0.065938	CG
22	EXP 57	+	-	+	-	+	-	0.42	0.24	0.10	0.00	0.15	0.00	0.09	32	0.002812	ACG
23	EXP 09	-	+	+	-	+	-	0.38	0.42	0.01	0.07	0.08	-0.01	0.09	32	0.002813	FCG
24	EXP 41	+	+	+	-	+	-	0.44	0.42	0.09	0.07	0.14	-0.00	0.07	32	0.002187	AFCG
25	EXP 21	-	-	-	+	+	-	0.19	0.42	0.00	0.00	0.00	0.03	0.03	32	0.000938	IG
26	EXP 53	+	-	-	+	+	-	0.19	0.44	0.04	0.00	0.03	0.04	-0.07	32	-0.002187	AIG
27	EXP 05	-	+	-	+	+	-	0.19	0.85	0.00	0.03	0.00	0.01	0.01	32	0.000313	FIG
28	EXP 37	+	+	-	+	+	-	0.2	0.90	0.04	0.02	0.06	0.04	-0.01	32	-0.000313	AFIG
29	EXP 29	-	-	+	+	+	-	0.38	0.40	0.04	0.00	0.00	0.01	0.15	32	0.004688	CIG
30	EXP 61	+	-	+	+	+	-	0.42	0.42	0.09	0.00	0.01	0.00	0.05	32	0.001563	ACIG
31	EXP 13	-	+	+	+	+	-	0.39	0.87	0.00	0.03	0.00	-0.01	0.01	32	0.000313	FCIG
32	EXP 45	+	+	+	+	+	-	0.44	0.92	0.09	0.03	0.06	0.00	-0.01	32	-0.000313	AFCIG

Table 21B. Yate's algorithm, Results for Ratio On Time

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio On Time	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	–	–	–	–	–	+	0.12	0.00	0.00	0.34	0.00	2.21	0.49	32	0.015313	S
34	EXP 50	+	–	–	–	–	+	0.12	0.00	0.00	0.34	–0.01	2.54	–0.05	32	–0.001562	AS
35	EXP 02	–	+	–	–	–	+	0.12	0.03	0.00	0.83	–0.04	0.11	0.07	32	0.002187	FS
36	EXP 34	+	+	–	–	–	+	0.12	0.03	0.00	0.86	0.00	0.14	0.01	32	0.000312	AFS
37	EXP 26	–	–	+	–	–	+	0.21	0.00	0.01	0.40	0.00	0.07	0.25	32	0.007812	CS
38	EXP 58	+	–	+	–	–	+	0.23	0.00	0.02	0.36	–0.03	0.14	–0.05	32	–0.001562	ACS
39	EXP 10	–	+	+	–	–	+	0.21	0.03	0.01	0.89	–0.00	0.05	0.03	32	0.000938	FCS
40	EXP 42	+	+	+	–	–	+	0.23	0.03	0.03	0.97	–0.04	0.06	0.05	32	0.001562	AFCS
41	EXP 22	–	–	–	+	–	+	0.12	0.01	0.00	0.06	0.00	1.01	–0.03	32	–0.000938	IS
42	EXP 54	+	–	–	+	–	+	0.12	0.02	0.00	0.06	0.01	1.10	–0.01	32	–0.000313	AIS
43	EXP 06	–	+	–	+	–	+	0.12	0.04	0.00	0.07	0.00	0.03	–0.01	32	–0.000313	FIS
44	EXP 38	+	+	–	+	–	+	0.12	0.06	0.00	0.08	0.00	0.08	0.01	32	0.000312	AFIS
45	EXP 30	–	–	+	+	–	+	0.2	0.00	0.02	0.04	0.00	0.03	0.01	32	0.000313	CIS
46	EXP 62	+	–	+	+	–	+	0.22	0.01	0.05	0.04	–0.01	0.06	0.03	32	0.000937	ACIS
47	EXP 14	–	+	+	+	–	+	0.2	0.04	0.02	0.05	0.00	0.01	–0.01	32	–0.000313	FCIS
48	EXP 46	+	+	+	+	–	+	0.22	0.05	0.05	0.09	–0.00	0.06	0.01	32	0.000313	AFCIS
49	EXP 16	–	–	–	–	+	+	0.2	0.00	0.00	0.00	0.00	–0.01	0.33	32	0.010313	GS
50	EXP 48	+	–	–	–	+	+	0.22	0.00	0.00	0.00	0.03	0.04	0.03	32	0.000938	AGS
51	EXP 00	–	+	–	–	+	+	0.21	0.02	0.00	0.01	–0.04	–0.03	0.07	32	0.002187	FGS
52	EXP 32	+	+	–	–	+	+	0.23	0.02	0.00	0.02	0.08	–0.04	0.01	32	0.000312	AFGS
53	EXP 24	–	–	+	–	+	+	0.41	0.00	0.01	0.00	0.00	0.01	0.09	32	0.002812	CGS
54	EXP 56	+	–	+	–	+	+	0.44	0.00	0.02	0.00	0.01	0.00	0.03	32	0.000938	ACGS
55	EXP 08	–	+	+	–	+	+	0.42	0.02	0.01	0.03	–0.00	–0.01	0.03	32	0.000938	FCGS
56	EXP 40	+	+	+	–	+	+	0.48	0.02	0.01	0.03	0.04	–0.00	0.05	32	0.001562	AFCGS
57	EXP 20	–	–	–	+	+	+	0.2	0.02	0.00	0.00	0.00	0.03	0.05	32	0.001562	IGS
58	EXP 52	+	–	–	+	+	+	0.2	0.02	0.00	0.00	0.01	0.12	–0.01	32	–0.000312	AIGS
59	EXP 04	–	+	–	+	+	+	0.21	0.03	0.00	0.01	0.00	0.01	–0.01	32	–0.000313	FIGS
60	EXP 36	+	+	–	+	+	+	0.21	0.06	0.00	0.00	0.00	0.04	0.01	32	0.000312	AFIGS
61	EXP 28	–	–	+	+	+	+	0.42	0.00	0.00	0.00	0.00	0.01	0.09	32	0.002812	CIGS
62	EXP 60	+	–	+	+	+	+	0.45	0.00	0.03	0.00	–0.01	0.00	0.03	32	0.000938	ACIGS
63	EXP 12	–	+	+	+	+	+	0.43	0.03	0.00	0.03	0.00	–0.01	–0.01	32	–0.000313	FCIGS
64	EXP 44	+	+	+	+	+	+	0.49	0.06	0.03	0.03	0.00	0.00	0.01	32	0.000313	AFCIGS

Table 22A Yate's algorithm, Results for Ratio Delivered

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio Delivered	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	–	–	–	–	–	–	0.26	0.52	1.04	3.17	6.32	17.78	36.34	64	0.567813	average
2	EXP 51	+	–	–	–	–	–	0.26	0.52	2.13	3.15	11.46	18.56	0.62	32	0.019375	A
3	EXP 03	–	+	–	–	–	–	0.26	1.07	1.04	5.69	6.50	0.32	0.52	32	0.016250	F
4	EXP 35	+	+	–	–	–	–	0.26	1.06	2.11	5.77	12.06	0.30	0.20	32	0.006250	AF
5	EXP 27	–	–	+	–	–	–	0.52	0.52	2.01	3.32	0.12	0.22	10.84	32	0.338750	C
6	EXP 59	+	–	+	–	–	–	0.55	0.52	3.68	3.18	0.20	0.30	0.08	32	0.002500	AC
7	EXP 11	–	+	+	–	–	–	0.51	1.06	2.06	6.02	0.10	0.08	–0.18	32	–0.005625	FC
8	EXP 43	+	+	+	–	–	–	0.55	1.05	3.71	6.04	0.20	0.12	0.14	32	0.004375	AFC
9	EXP 23	–	–	–	+	–	–	0.26	0.98	1.04	0.07	–0.02	5.48	–0.06	32	–0.001875	I
10	EXP 55	+	–	–	+	–	–	0.26	1.03	2.28	0.05	0.24	5.36	–0.02	32	–0.000625	AI
11	EXP 07	–	+	–	+	–	–	0.26	1.81	1.04	0.09	0.00	0.06	0.08	32	0.002500	FI
12	EXP 39	+	+	–	+	–	–	0.26	1.87	2.14	0.11	0.30	0.02	0.00	32	0.000000	AFI
13	EXP 31	–	–	+	+	–	–	0.52	0.98	2.27	0.04	0.02	–0.08	–0.12	32	–0.003750	CI
14	EXP 63	+	–	+	+	–	–	0.54	1.08	3.75	0.06	0.06	–0.10	0.00	32	0.000000	ACI
15	EXP 15	–	+	+	+	–	–	0.51	1.84	2.25	0.12	0.00	0.06	–0.14	32	–0.004375	FCI
16	EXP 47	+	+	+	+	–	–	0.54	1.87	3.79	0.08	0.12	0.08	0.02	32	0.000625	AFCI
17	EXP 17	–	–	–	–	+	–	0.48	0.52	0.00	–0.01	2.16	0.06	10.70	32	0.334375	G
18	EXP 49	+	–	–	–	+	–	0.5	0.52	0.07	–0.01	3.32	–0.12	0.16	32	0.005625	AG
19	EXP 01	–	+	–	–	+	–	0.5	1.14	0.00	0.11	2.34	0.00	0.56	32	0.017500	FG
20	EXP 33	+	+	–	–	+	–	0.53	1.14	0.05	0.13	3.02	–0.02	0.16	32	0.005000	AFG
21	EXP 25	–	–	+	–	+	–	0.9	0.52	0.05	0.00	0.12	0.02	1.84	32	0.057500	CG
22	EXP 57	+	–	+	–	+	–	0.91	0.52	0.04	0.00	–0.06	0.06	–0.36	32	–0.011250	ACG
23	EXP 09	–	+	+	–	+	–	0.92	1.07	0.08	0.12	0.10	0.00	–0.14	32	–0.004375	FCG
24	EXP 41	+	+	+	–	+	–	0.95	1.07	0.03	0.18	–0.08	0.00	0.10	32	0.003125	AFCG
25	EXP 21	–	–	–	+	+	–	0.47	1.10	0.00	0.01	–0.02	–0.04	0.26	32	0.008125	IG
26	EXP 53	+	–	–	+	+	–	0.51	1.17	0.04	0.01	–0.06	–0.08	–0.02	32	–0.000625	AIG
27	EXP 05	–	+	–	+	+	–	0.52	1.85	0.00	0.03	0.00	–0.06	0.08	32	0.002500	FIG
28	EXP 37	+	+	–	+	+	–	0.56	1.90	0.06	0.03	–0.10	0.06	0.00	32	0.000000	AFIG
29	EXP 29	–	–	+	+	+	–	0.92	1.06	0.09	0.00	0.02	–0.08	0.20	32	0.006250	CIG
30	EXP 61	+	–	+	+	+	–	0.92	1.19	0.03	0.00	0.04	–0.06	–0.00	32	–0.000000	ACIG
31	EXP 13	–	+	+	+	+	–	0.92	1.87	0.05	0.06	0.00	0.02	–0.14	32	–0.004375	FCIG
32	EXP 45	+	+	+	+	+	–	0.95	1.92	0.03	0.06	0.08	0.00	0.02	32	0.000625	AFCIG

Table 22B. Yate's algorithm, Results for Ratio Delivered

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio Delivered	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	−	−	−	−	−	+	0.26	0.00	0.00	1.09	−0.02	5.14	0.78	32	0.024375	S
34	EXP 50	+	−	−	−	−	+	0.26	0.00	−0.01	1.07	0.08	5.56	−0.02	32	−0.000625	AS
35	EXP 02	−	+	−	−	−	+	0.26	0.03	0.00	1.67	−0.14	0.08	0.08	32	0.002500	FS
36	EXP 34	+	+	−	−	−	+	0.26	0.04	−0.01	1.65	0.02	0.10	0.04	32	0.001250	AFS
37	EXP 26	−	−	+	−	−	+	0.56	0.00	0.05	1.24	−0.02	0.26	−0.12	32	−0.003750	CS
38	EXP 58	+	−	+	−	−	+	0.58	0.00	0.06	1.10	0.02	0.30	−0.04	32	−0.001250	ACS
39	EXP 10	−	+	+	−	−	+	0.56	0.02	0.10	1.48	0.02	0.04	−0.02	32	−0.000625	FCS
40	EXP 42	+	+	+	−	−	+	0.58	0.03	0.03	1.54	−0.04	0.12	0.02	32	0.000625	AFCS
41	EXP 22	−	−	−	+	−	+	0.26	0.02	0.00	0.07	0.00	1.16	−0.18	32	−0.005625	IS
42	EXP 54	+	−	−	+	−	+	0.26	0.03	0.00	0.05	0.02	0.68	−0.02	32	−0.000625	AIS
43	EXP 06	−	+	−	+	−	+	0.26	0.01	0.00	−0.01	0.00	−0.18	0.04	32	0.001250	FIS
44	EXP 38	+	+	−	+	−	+	0.26	0.03	0.00	−0.05	0.06	−0.18	0.00	32	0.000000	AFIS
45	EXP 30	−	−	+	+	−	+	0.52	0.04	0.07	0.04	0.00	−0.04	−0.04	32	−0.001250	CIS
46	EXP 62	+	−	+	+	−	+	0.55	0.04	0.05	0.06	0.00	−0.10	0.12	32	0.003750	ACIS
47	EXP 14	−	+	+	+	−	+	0.52	0.00	0.13	−0.06	0.00	0.02	0.02	32	0.000625	FCIS
48	EXP 46	+	+	+	+	−	+	0.55	0.03	0.05	−0.02	0.00	0.08	−0.02	32	−0.000625	AFCIS
49	EXP 16	−	−	−	−	+	+	0.53	0.00	0.00	−0.01	−0.02	0.10	0.42	32	0.013125	GS
50	EXP 48	+	−	−	−	+	+	0.57	0.00	0.01	−0.01	−0.02	0.16	0.02	32	0.000625	AGS
51	EXP 00	−	+	−	−	+	+	0.56	0.02	0.00	0.01	−0.14	0.04	0.04	32	0.001250	FGS
52	EXP 32	+	+	−	−	+	+	0.61	0.02	0.01	−0.07	0.06	−0.06	0.08	32	0.002500	AFGS
53	EXP 24	−	−	+	−	+	+	0.93	0.00	0.01	0.00	−0.02	0.02	−0.48	32	−0.015000	CGS
54	EXP 56	+	−	+	−	+	+	0.92	0.00	0.02	0.00	−0.04	0.06	0.00	32	0.000000	ACGS
55	EXP 08	−	+	+	−	+	+	0.93	0.03	0.00	−0.02	0.02	0.00	−0.06	32	−0.001875	FCGS
56	EXP 40	+	+	+	−	+	+	0.97	0.03	0.03	−0.08	0.04	0.00	0.06	32	0.001875	AFCGS
57	EXP 20	−	−	−	+	+	+	0.52	0.04	0.00	0.01	0.00	0.00	0.06	32	0.001875	IGS
58	EXP 52	+	−	−	+	+	+	0.54	0.05	0.00	0.01	−0.08	0.20	−0.10	32	−0.003125	AIGS
59	EXP 04	−	+	−	+	+	+	0.58	−0.01	0.00	0.01	0.00	−0.02	0.04	32	0.001250	FIGS
60	EXP 36	+	+	−	+	+	+	0.61	0.04	0.00	0.03	−0.06	0.02	0.00	32	0.000000	AFIGS
61	EXP 28	−	−	+	+	+	+	0.94	0.02	0.01	0.00	0.00	−0.08	0.20	32	0.006250	CIGS
62	EXP 60	+	−	+	+	+	+	0.93	0.03	0.05	0.00	0.02	−0.06	0.04	32	0.001250	ACIGS
63	EXP 12	−	+	+	+	+	+	0.94	−0.01	0.01	0.04	0.00	0.02	0.02	32	0.000625	FCIGS
64	EXP 44	+	+	+	+	+	+	0.98	0.04	0.05	0.04	0.00	0.00	−0.02	32	−0.000625	AFCIGS

Table 23A. Yate's algorithm, Results for Total Flight Hours

Test Condition Number	Run Number	A	F	C	I	G	S	Total Flight Hours	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
1	EXP 19	-	-	-	-	-	-	1106	2685	5380	9872	15396	47540	100913	64	1576.766	average
2	EXP 51	+	-	-	-	-	-	1579	2675	4512	5524	32144	53373	12897	32	403.031	A
3	EXP 03	-	+	-	-	-	-	1127	2284	2523	22157	16745	6832	-991	32	-30.969	F
4	EXP 35	+	+	-	-	-	-	1548	2228	3001	9987	36628	6065	-731	32	-22.844	AF
5	EXP 27	-	-	+	-	-	-	960	1273	15977	10666	2226	-284	-33273	32	-1039.781	C
6	EXP 59	+	-	+	-	-	-	1324	1250	6180	6079	4606	-707	-6757	32	-211.156	AC
7	EXP 11	-	+	+	-	-	-	939	1502	6934	25652	1761	-188	547	32	17.094	FC
8	EXP 43	+	+	+	-	-	-	1289	1499	3053	10976	4304	-543	1395	32	43.594	AFC
9	EXP 23	-	-	-	+	-	-	594	7959	5875	1608	-92	-14048	-35781	32	-1118.156	I
10	EXP 55	+	-	-	+	-	-	679	8018	4791	618	-192	-19225	-7573	32	-236.656	AI
11	EXP 07	-	+	-	+	-	-	591	3121	2947	3665	-261	-3392	-329	32	-10.281	FI
12	EXP 39	+	+	-	+	-	-	659	3059	3132	941	-446	-3365	-69	32	-2.156	AFI
13	EXP 31	-	-	+	+	-	-	636	3533	19550	1160	-78	-72	17081	32	533.781	CI
14	EXP 63	+	-	+	+	-	-	866	3401	6102	601	-110	619	6317	32	197.406	ACI
15	EXP 15	-	+	+	+	-	-	632	1555	7927	3802	-149	356	73	32	2.281	FCI
16	EXP 47	+	+	+	+	-	-	867	1498	3049	502	-394	1039	-263	32	-8.219	AFCI
17	EXP 17	-	-	-	-	+	-	3128	3097	894	-66	-370	-16518	36631	32	1144.719	G
18	EXP 49	+	-	-	-	+	-	4831	2778	714	-26	-13678	-19263	4923	32	153.844	AG
19	EXP 01	-	+	-	-	+	-	3210	2354	153	-3	-899	-3714	-285	32	-8.906	FG
20	EXP 33	+	+	-	-	+	-	4808	2437	465	-189	-18326	-3859	-277	32	-8.656	AFG
21	EXP 25	-	-	+	-	+	-	1484	1467	3301	-236	132	-146	-30735	32	-960.469	CG
22	EXP 57	+	-	+	-	+	-	1637	1480	364	-25	-3524	-183	-7199	32	-224.969	ACG
23	EXP 09	-	+	+	-	+	-	1424	1585	764	-26	89	38	-103	32	-3.219	FCG
24	EXP 41	+	+	+	-	+	-	1635	1547	177	-420	-3454	-107	661	32	20.656	AFCG
25	EXP 21	-	-	-	+	+	-	1551	9782	655	-66	-26	7242	-17911	32	-559.719	IG
26	EXP 53	+	-	-	+	+	-	1982	9768	505	-12	-46	9839	-4475	32	-139.844	AIG
27	EXP 05	-	+	-	+	+	-	1534	3057	181	-47	351	2842	-831	32	-25.969	FIG
28	EXP 37	+	+	-	+	+	-	1867	3045	420	-63	268	3475	-383	32	-11.969	AFIG
29	EXP 29	-	-	+	+	+	-	742	4135	3536	-126	60	262	11891	32	371.594	CIG
30	EXP 61	+	-	+	+	+	-	813	3792	266	-23	296	-189	4555	32	142.344	ACIG
31	EXP 13	-	+	+	+	+	-	696	1563	343	-92	307	-46	847	32	26.469	FCIG
32	EXP 45	+	+	+	+	+	-	802	1486	159	-302	732	-217	467	32	14.594	AFCIG

Table 23B. Yate's algorithm. Results for Total Flight Hours

Test Condition Number	Run Number	A	F	C	I	G	S	Total Flight Hours	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	-	-	-	-	-	+	1328	473	-10	-848	-4348	16748	5833	32	182.281	S
34	EXP 50	+	-	-	-	-	+	1789	421	-56	478	-12170	19883	-767	32	-23.969	AS
35	EXP 02	-	+	-	-	-	+	1282	364	-23	-9797	-4587	2380	-423	32	-13.219	FS
36	EXP 34	+	+	-	-	-	+	1496	350	-3	-3881	-14676	2543	-355	32	-11.094	AFS
37	EXP 26	-	-	+	-	-	+	1076	85	59	-1084	-990	-100	-5177	32	-161.781	CS
38	EXP 58	+	-	+	-	-	+	1278	68	-62	185	-2724	-185	27	32	0.844	ACS
39	EXP 10	-	+	+	-	-	+	1067	230	-132	-13448	-559	-32	691	32	21.594	FCS
40	EXP 42	+	+	+	-	-	+	1370	235	-57	-4878	-3300	-245	683	32	21.344	AFCS
41	EXP 22	-	-	-	+	-	+	688	1703	-319	-180	40	-13308	-2745	32	-85.781	IS
42	EXP 54	+	-	-	+	-	+	779	1598	83	312	-186	-17427	-145	32	-4.531	AIS
43	EXP 06	-	+	-	+	-	+	695	153	13	-2937	211	-3656	-37	32	-1.156	FIS
44	EXP 38	+	+	-	+	-	+	785	211	-38	-587	-394	-3543	-145	32	-4.531	AFIS
45	EXP 30	-	-	+	+	-	+	682	431	-14	-150	54	-20	2597	32	81.156	CIS
46	EXP 62	+	-	+	+	-	+	903	333	-12	239	-16	-83	633	32	19.781	ACIS
47	EXP 14	-	+	+	+	-	+	674	71	-343	-3270	103	236	-451	32	-14.094	FCIS
48	EXP 46	+	+	+	+	-	+	873	106	-77	-184	-210	425	-171	32	-5.344	AFCIS
49	EXP 16	-	-	-	-	+	+	3958	441	-52	-46	1326	-7822	3135	32	97.969	GS
50	EXP 48	+	-	-	-	+	+	5824	214	-14	20	5916	-10089	163	32	5.094	AGS
51	EXP 00	-	+	-	-	+	+	4049	202	-17	-121	1269	-1734	-85	32	-2.656	FGS
52	EXP 32	+	+	-	-	+	+	5719	303	5	75	8570	-2741	-213	32	-6.656	AFGS
53	EXP 24	-	-	+	-	+	+	1488	91	-105	402	492	-226	-4119	32	-128.719	CGS
54	EXP 56	+	-	+	-	+	+	1589	90	58	-51	2350	-605	113	32	3.531	ACGS
55	EXP 08	-	+	+	-	+	+	1430	221	-98	2	389	-70	-63	32	-1.969	FCGS
56	EXP 40	+	+	+	-	+	+	1615	199	35	286	3086	-313	189	32	5.906	AFCGS
57	EXP 20	-	-	-	+	+	+	1890	1866	-227	38	66	4590	-2267	32	-70.844	IGS
58	EXP 52	+	-	-	+	+	+	2245	1670	101	22	196	7301	-1007	32	-31.469	AIGS
59	EXP 04	-	+	-	+	+	+	1902	81	-1	163	-453	1858	-379	32	-11.844	FIGS
60	EXP 36	+	+	-	+	+	+	1890	185	-22	133	264	2697	-243	32	-7.594	AFIGS
61	EXP 28	-	-	+	+	+	+	758	355	-196	328	-16	130	2711	32	84.719	CIGS
62	EXP 60	+	-	+	+	+	+	805	-12	104	-21	-30	717	839	32	26.219	ACIGS
63	EXP 12	-	+	+	+	+	+	687	47	-367	300	-349	-14	587	32	18.344	FCIGS
64	EXP 44	+	+	+	+	+	+	799	112	65	432	132	481	495	32	15.469	AFCIGS

Table 24A. Yate's algorithm, Results for Total Sorties Flown

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Total Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi- fication
1	EXP 19	−	−	−	−	−	−	2494	6003	11970	21321	43872	122482	258554	64	4039.906	average
2	EXP 51	+	−	−	−	−	−	3509	5967	9351	22551	78610	136072	30596	32	956.125	A
3	EXP 03	−	+	−	−	−	−	2544	4744	11168	41874	48073	16372	−4444	32	−138.875	F
4	EXP 35	+	+	−	−	−	−	3423	4607	11383	36736	87999	14224	−2182	32	−68.188	AF
5	EXP 27	−	−	+	−	−	−	2032	5644	30043	23273	5278	−1326	−78524	32	−2453.875	C
6	EXP 59	+	−	+	−	−	−	2712	5524	11831	24800	11094	−3118	−16742	32	−523.188	AC
7	EXP 11	−	+	+	−	−	−	1980	5701	24571	47880	4313	−560	2186	32	68.313	FC
8	EXP 43	+	+	+	−	−	−	2827	5682	12165	40119	9911	−1622	3484	32	108.875	AFC
9	EXP 23	−	−	−	+	−	−	2650	15011	13324	3221	−312	−33022	−10142	32	−316.938	I
10	EXP 55	+	−	−	+	−	−	2994	15032	9949	2057	−1014	−45502	−9924	32	−310.125	AI
11	EXP 07	−	+	−	+	−	−	2818	8001	13126	7244	−921	−8480	−1520	32	−47.500	FI
12	EXP 39	+	+	−	+	−	−	2906	5830	11674	3850	−2197	−8262	−850	32	−26.563	AFI
13	EXP 31	−	−	+	+	−	−	2495	12579	38256	2183	−222	118	19152	32	598.500	CI
14	EXP 63	+	−	+	+	−	−	3206	11992	11824	2130	−338	2068	11054	32	345.438	ACI
15	EXP 15	−	+	+	+	−	−	2484	6221	28081	7612	−293	864	314	32	9.813	FCI
16	EXP 47	+	+	+	+	−	−	3198	5944	12038	2299	−1329	2620	492	32	15.375	AFCI
17	EXP 17	−	−	−	−	+	−	5800	7145	1894	−173	−2404	−3908	74664	32	2333.250	G
18	EXP 49	+	−	−	−	+	−	9211	6179	1327	−139	−30818	−6234	11414	32	356.688	AG
19	EXP 01	−	+	−	−	+	−	5892	4900	632	−150	−4827	−4558	−1978	32	−61.813	FG
20	EXP 33	+	+	−	−	+	−	9140	5049	1425	−864	−40675	−5366	−1152	32	−36.000	AFG
21	EXP 25	−	−	+	−	+	−	2881	6543	8659	−817	226	−680	−64082	32	−2001.938	CG
22	EXP 57	+	−	+	−	+	−	3120	6583	585	−104	−8706	−840	−17196	32	−537.375	ACG
23	EXP 09	−	+	+	−	+	−	2742	5909	3241	−322	1	−110	324	32	10.125	FCG
24	EXP 41	+	+	+	−	+	−	3088	5765	609	−1875	−8263	−740	2002	32	62.563	AFCG
25	EXP 21	−	−	−	+	+	−	5390	18237	1288	−169	0	8640	−15656	32	−489.250	IG
26	EXP 53	+	−	−	+	+	−	7189	18019	895	−53	118	10512	−7490	32	−234.063	AIG
27	EXP 05	−	+	−	+	+	−	5275	5864	868	−56	931	4802	−3014	32	−94.188	FIG
28	EXP 37	+	+	−	+	+	−	6717	5760	1262	−282	1137	6252	−1340	32	−41.875	AFIG
29	EXP 29	−	−	+	+	+	−	2977	14765	7238	−211	162	704	9638	32	301.188	CIG
30	EXP 61	+	−	+	+	+	−	3244	13316	374	−82	702	−390	6760	32	211.250	ACIG
31	EXP 13	−	+	+	+	+	−	2801	6232	1849	−230	579	118	2508	32	78.375	FCIG
32	EXP 45	+	+	+	+	+	−	3143	5806	450	−1099	2041	374	2050	32	64.063	AFCIG

Table 24B. Yate's algorithm, Results for Total Sorties Flown

Test Condition Number	Run Number	A	F	C	I	G	S	Total Sorties Flown	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
		Design Matrix Variables							Algorithm								
33	EXP 18	−	−	−	−	−	+	3142	1015	−36	−2619	1230	34738	13590	32	424.688	S
34	EXP 50	+	−	−	−	−	+	4003	879	−137	215	−5138	39926	−2148	32	−67.125	AS
35	EXP 02	−	+	−	−	−	+	2876	680	−120	−18212	1527	5816	−1792	32	−56.000	FS
36	EXP 34	+	+	−	−	−	+	3303	647	−19	−12406	−7761	5598	−1062	32	−33.188	AFS
37	EXP 26	−	−	+	−	−	+	2282	344	21	−3375	−1164	−702	−12480	32	−390.000	CS
38	EXP 58	+	−	+	−	−	+	2618	288	−171	−1452	−3394	−1276	218	32	6.813	ACS
39	EXP 10	−	+	+	−	−	+	2245	711	−587	−24632	−53	−116	1950	32	60.938	FCS
40	EXP 42	+	+	+	−	−	+	2804	714	−277	−16043	−5313	−1036	1756	32	54.875	AFCS
41	EXP 22	−	−	−	+	−	+	3054	3411	−966	−567	34	−28214	−2326	32	−72.688	IS
42	EXP 54	+	−	−	+	−	+	3489	3248	149	793	−714	−35848	−808	32	−25.250	AIS
43	EXP 06	−	+	−	+	−	+	3075	239	40	−6074	713	−8932	−160	32	−5.000	FIS
44	EXP 38	+	+	−	+	−	+	3508	346	−144	−2632	−1553	−8264	−630	32	−19.688	AFIS
45	EXP 30	−	−	+	+	−	+	2619	1799	−218	−393	116	118	1872	32	58.500	CIS
46	EXP 62	+	−	+	+	−	+	3290	1442	−104	394	−226	206	1450	32	45.313	ACIS
47	EXP 14	−	+	+	+	−	+	2587	267	−1449	−6864	129	540	−1094	32	−34.188	FCIS
48	EXP 46	+	+	+	+	−	+	3178	342	−426	−1399	−869	1462	256	32	8.000	AFCIS
49	EXP 16	−	−	−	−	+	+	7222	861	−136	−101	2834	−6368	5188	32	162.125	GS
50	EXP 48	+	−	−	−	+	+	11015	427	−33	101	5806	−9288	−218	32	−6.813	AGS
51	EXP 00	−	+	−	−	+	+	7287	336	−56	−192	1923	−2230	−574	32	−17.938	FGS
52	EXP 32	+	+	−	−	+	+	10732	559	3	310	8589	−5260	−920	32	−28.750	AFGS
53	EXP 24	−	−	+	−	+	+	2868	435	−163	1115	1360	−748	−7634	32	−238.563	CGS
54	EXP 56	+	−	+	−	+	+	2996	433	107	−184	3442	−2266	668	32	20.875	ACGS
55	EXP 08	−	+	+	−	+	+	2757	671	−357	114	787	−342	88	32	2.750	FCGS
56	EXP 40	+	+	+	−	+	+	3003	591	75	1023	5465	−998	922	32	28.813	AFCGS
57	EXP 20	−	−	−	+	+	+	6586	3793	−434	103	202	2972	−2920	32	−91.250	IGS
58	EXP 52	+	−	−	+	+	+	8179	3445	223	59	502	6666	−3030	32	−94.688	AIGS
59	EXP 04	−	+	−	+	+	+	6530	128	−2	270	−1299	2082	−1518	32	−47.438	FIGS
60	EXP 36	+	+	−	+	+	+	6786	246	−80	432	909	4678	−656	32	−20.500	AFIGS
61	EXP 28	−	−	+	+	+	+	3063	1593	−348	657	−44	300	3894	32	115.438	CIGS
62	EXP 60	+	−	+	+	+	+	3169	256	118	−78	162	2208	2596	32	81.125	ACIGS
63	EXP 12	−	+	+	+	+	+	2731	106	−1337	466	−735	206	1908	32	59.625	FCIGS
64	EXP 44	+	+	+	+	+	+	3075	344	238	1575	1109	1844	1638	32	51.188	AFCIGS

Table 25A. Yate's algorithm, Results for Productive Flight Hours

Test Condition Number	Run Number	A	F	C	I	G	S	Productive Flight Hours	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
		Design Matrix Variables							Algorithm								
1	EXP 19	−	−	−	−	−	−	111	231	462	1817	3059	9299	18926	64	295.7188	average
2	EXP 51	+	−	−	−	−	−	120	231	1355	1242	6240	9627	1170	32	36.5625	A
3	EXP 03	−	+	−	−	−	−	109	676	220	4294	3218	605	−130	32	−4.0625	F
4	EXP 35	+	+	−	−	−	−	122	679	1022	1946	6409	565	130	32	4.0626	AF
5	EXP 27	−	−	+	−	−	−	295	110	1873	1933	349	−69	4894	32	152.9375	C
6	EXP 59	+	−	+	−	−	−	381	110	2421	1285	256	61	274	32	8.5625	AC
7	EXP 11	−	+	+	−	−	−	290	510	827	4407	300	69	−106	32	−3.3125	FC
8	EXP 43	+	+	+	−	−	−	389	512	1119	2002	265	61	90	32	2.8125	AFC
9	EXP 23	−	−	−	+	−	−	55	959	462	207	5	2535	−5976	32	−186.7500	I
10	EXP 55	+	−	−	+	−	−	55	914	1471	142	−74	2359	−336	32	−10.5000	AI
11	EXP 07	−	+	−	+	−	−	55	1222	223	192	10	169	140	32	4.3750	FI
12	EXP 39	+	+	−	+	−	−	55	1199	1062	64	−71	105	−68	32	−2.1250	AFI
13	EXP 31	−	−	+	+	−	−	222	401	2061	143	27	−29	−576	32	−18.0000	CI
14	EXP 63	+	−	+	+	−	−	288	426	2343	157	42	−77	232	32	7.2500	ACI
15	EXP 15	−	+	+	+	−	−	218	575	888	211	−12	37	−148	32	−4.6250	FCI
16	EXP 47	+	+	+	+	−	−	294	544	1114	54	73	53	12	32	0.3750	AFCI
17	EXP 17	−	−	−	−	+	−	448	226	22	3	1695	−2923	6372	32	199.1250	G
18	EXP 49	+	−	−	−	+	−	511	236	185	2	840	−3053	−128	32	−4.0000	AG
19	EXP 01	−	+	−	−	+	−	415	734	0	−68	1848	−193	−160	32	−5.0000	FG
20	EXP 33	+	+	−	−	+	−	499	737	142	−6	511	−143	100	32	3.1250	AFG
21	EXP 25	−	−	+	−	+	−	604	111	147	13	305	61	−2192	32	−68.5000	CG
22	EXP 57	+	−	+	−	+	−	618	112	45	−3	−136	79	−884	32	−27.6250	ACG
23	EXP 09	−	+	+	−	+	−	584	533	49	−83	274	−41	−92	32	−2.8750	FCG
24	EXP 41	+	+	+	−	+	−	615	529	15	12	−169	−27	56	32	1.7500	AFCG
25	EXP 21	−	−	−	+	+	−	186	1052	12	17	5	−347	−3530	32	−110.3125	IG
26	EXP 53	+	−	−	+	+	−	215	1009	131	10	−34	−229	−234	32	−7.3125	AIG
27	EXP 05	−	+	−	+	+	−	203	1193	1	38	−12	47	174	32	5.4375	FIG
28	EXP 37	+	+	−	+	+	−	223	1153	156	4	−65	185	−66	32	−2.0625	AFIG
29	EXP 29	−	−	+	+	+	−	287	424	185	−9	19	−79	−54	32	−1.6875	CIG
30	EXP 61	+	−	+	+	+	−	288	464	26	−3	18	−69	202	32	6.3125	ACIG
31	EXP 13	−	+	+	+	+	−	265	571	32	53	−2	27	−150	32	−4.6875	FCIG
32	EXP 45	+	+	+	+	+	−	279	543	22	20	55	−15	10	32	0.3125	AFCIG

Table 25B Yate's algorithm, Results for Productive Flight Hours

Test Condition Number	Run Number	A	F	C	I	G	S	Productive Flight Hours	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
33	EXP 18	–	–	–	–	–	+	109	9	0	893	-575	3181	328	32	10.2500	S
34	EXP 50	+	–	–	–	–	+	117	13	3	802	-2348	3191	-40	32	-1.2500	AS
35	EXP 02	–	+	–	–	–	+	118	86	0	548	-648	-93	8	32	0.2500	FS
36	EXP 34	+	+	–	–	–	+	120	99	2	292	-2405	-35	-8	32	-0.2500	AFS
37	EXP 26	–	–	+	–	–	+	333	0	-45	1009	-65	-79	-176	32	-5.5000	CS
38	EXP 58	+	–	+	–	–	+	401	0	-23	839	-128	-81	-64	32	-2.0000	ACS
39	EXP 10	–	+	+	–	–	+	337	66	25	285	14	15	-48	32	-1.5000	FCS
40	EXP 42	+	+	+	–	–	+	400	76	-31	228	-157	85	16	32	0.5000	AFCS
41	EXP 22	–	–	–	+	–	+	55	63	10	163	-1	-855	-130	32	-4.0625	IS
42	EXP 54	+	–	–	+	–	+	56	84	3	142	62	-1337	50	32	1.5625	AIS
43	EXP 06	–	+	–	+	–	+	56	14	1	-102	-16	-441	18	32	0.5625	FIS
44	EXP 33	+	+	–	+	–	+	56	31	-4	-34	95	-443	14	32	0.4375	AFIS
45	EXP 30	–	–	+	+	–	+	227	29	-43	119	-7	-39	118	32	3.6875	CIS
46	EXP 62	+	–	+	+	–	+	306	20	-40	155	-34	-53	138	32	4.3125	ACIS
47	EXP 14	–	+	+	+	–	+	228	1	40	-159	6	-1	10	32	0.3125	FCIS
48	EXP 46	+	+	+	+	–	+	303	14	-28	-10	-53	57	-42	32	-1.3125	AFCIS
49	EXP 16	–	–	–	–	+	+	482	8	4	3	-91	-1773	10	32	0.3125	GS
50	EXP 48	+	–	–	–	+	+	570	4	13	2	-256	-1757	58	32	1.8125	AGS
51	EXP 00	–	+	–	–	+	+	456	68	0	22	-170	-63	-2	32	-0.0625	FGS
52	EXP 32	+	+	–	–	+	+	553	63	10	-56	-59	-171	70	32	2.1875	AFGS
53	EXP 24	–	–	+	–	+	+	601	1	21	-7	-21	63	-482	32	-15.0625	CGS
54	EXP 56	+	–	+	–	+	+	592	0	17	-5	68	111	-2	32	-0.0625	ACGS
55	EXP 08	–	+	+	–	+	+	559	79	-9	3	36	-27	-14	32	-0.4375	FCGS
56	EXP 40	+	+	+	–	+	+	594	77	13	-68	149	-39	58	32	1.8125	AFCGS
57	EXP 20	–	–	–	+	+	+	204	88	-4	9	-1	-165	16	32	0.5000	IGS
58	EXP 52	+	–	–	+	+	+	220	97	-5	10	-78	111	-108	32	-3.3750	AIGS
59	EXP 04	–	+	–	+	+	+	224	-9	-1	-4	2	89	48	32	1.5000	FIGS
60	EXP 36	+	+	–	+	+	+	240	35	-2	22	-71	113	-12	32	-0.3750	AFIGS
61	EXP 28	–	–	+	+	+	+	285	16	9	-1	1	-77	276	32	8.6250	CIGS
62	EXP 60	+	–	+	+	+	+	286	16	44	-1	26	-73	24	32	0.7500	ACIGS
63	EXP 12	–	+	+	+	+	+	261	1	0	35	0	25	4	32	0.1250	FCIGS
64	EXP 44	+	+	+	+	+	+	282	21	20	20	-15	-15	-40	32	-1.2500	AFCIGS

Table 26A. Yate's algorithm, Results for Productive Sorties Flown

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Productive Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	–	–	–	–	–	–	331	683	1366	3972	8991	23798	48565	64	758.8281	average
2	EXP 51	+	–	–	–	–	–	352	683	2606	5019	14807	24767	2211	32	69.0938	A
3	EXP 03	–	+	–	–	–	–	327	1304	1292	7785	9422	1150	-311	32	-9.7188	F
4	EXP 35	+	+	–	–	–	–	356	1302	3727	7022	15345	1061	243	32	7.5938	AF
5	EXP 27	–	–	+	–	–	–	596	645	3393	4264	543	-184	10897	32	340.5313	C
6	EXP 59	+	–	+	–	–	–	708	647	4392	5158	607	-127	259	32	8.0938	AC
7	EXP 11	–	+	+	–	–	–	592	1863	3014	8100	474	96	-575	32	-17.9688	FC
8	EXP 43	+	+	+	–	–	–	710	1864	4008	7245	587	147	167	32	5.2188	AFC
9	EXP 23	–	–	–	+	–	–	324	1734	1380	280	1	5668	323	32	10.0938	I
10	EXP 55	+	–	–	+	–	–	321	1659	2884	263	-185	5229	-115	32	-3.5938	AI
11	EXP 07	–	+	–	+	–	–	324	2229	1311	339	8	172	247	32	7.7188	FI
12	EXP 39	+	+	–	+	–	–	323	2163	3847	268	-135	87	-75	32	-2.3438	AFI
13	EXP 31	–	–	+	+	–	–	870	1456	3816	164	37	-242	2475	32	77.3438	CI
14	EXP 63	+	–	+	+	–	–	993	1558	4284	310	59	-333	505	32	15.7813	ACI
15	EXP 15	–	+	+	+	–	–	860	2077	3262	380	4	62	-525	32	-16.4063	FCI
16	EXP 47	+	+	+	+	–	–	1004	1931	3983	207	143	105	77	32	2.4063	AFCI
17	EXP 17	–	–	–	–	+	–	816	676	50	-2	3675	284	11739	32	366.8438	G
18	EXP 49	+	–	–	–	+	–	918	704	230	3	1993	39	177	32	5.5313	AG
19	EXP 01	–	+	–	–	+	–	758	1448	-4	-141	4040	-88	-329	32	-10.2813	FG
20	EXP 33	+	+	–	–	+	–	901	1436	267	-44	1189	-27	161	32	5.0313	AFG
21	EXP 25	–	–	+	–	+	–	1097	655	245	16	451	102	-4533	32	-141.6563	CG
22	EXP 57	+	–	+	–	+	–	1132	656	94	-8	-279	145	-1499	32	-46.8438	ACG
23	EXP 09	–	+	+	–	+	–	1052	1928	198	-152	428	-62	-469	32	-14.6563	FCG
24	EXP 41	+	+	+	–	+	–	1111	1919	70	17	-341	-13	81	32	2.5313	AFCG
25	EXP 21	–	–	–	+	+	–	670	1948	22	14	-3	1190	-3559	32	-111.2188	IG
26	EXP 53	+	–	–	+	+	–	788	1868	142	23	-239	1285	-373	32	-11.6563	AIG
27	EXP 05	–	+	–	+	+	–	738	2178	1	65	-50	114	285	32	8.9063	FIG
28	EXP 37	+	+	–	+	+	–	820	2106	309	-6	-283	391	-101	32	-3.1563	AFIG
29	EXP 29	–	–	+	+	+	–	1028	1554	326	0	17	-256	-1979	32	-61.8438	CIG
30	EXP 61	+	–	+	+	+	–	1049	1708	54	4	45	-269	-53	32	-1.6563	ACIG
31	EXP 13	–	+	+	+	+	–	941	2060	138	80	26	100	-587	32	-18.3438	FCIG
32	EXP 45	+	+	+	+	+	–	990	1923	69	63	79	-23	63	32	1.9688	AFCIG

Table 28B. Yate's algorithm, Results for Productive Sorties Flown

Test Condition Number	Run Number	Design Matrix Variables A F C I G S	Productive Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	− − − − − +	330	21	0	1240	1047	5816	969	32	30.2813	S
34	EXP 50	+ − − − − +	346	29	−2	2435	−763	5923	−89	32	−2.7813	AS
35	EXP 02	− + − − − +	349	112	2	999	894	64	57	32	1.7813	FS
36	EXP 34	+ + − − − +	355	118	1	994	−855	113	51	32	1.5938	AFS
37	EXP 26	− − + − − +	691	−3	−75	1504	−17	−186	−439	32	−13.7188	CS
38	EXP 58	+ − + − − +	757	−1	−66	2536	−71	−143	−85	32	−2.6563	ACS
39	EXP 10	− + + − − +	680	123	102	468	146	22	−91	32	−2.8438	FCS
40	EXP 42	+ + + − − +	756	144	−146	721	−173	139	43	32	1.3438	AFCS
41	EXP 22	− − − + − +	327	102	28	180	5	−1682	−245	32	−7.6563	IS
42	EXP 54	+ − − + − +	328	143	−12	271	97	−2851	61	32	1.9063	AIS
43	EXP 06	− + − + − +	328	35	1	−151	−24	−730	43	32	1.3438	FIS
44	EXP 38	+ + − + − +	328	59	−9	−128	169	−769	49	32	1.5313	AFIS
45	EXP 30	− − + + − +	888	116	−80	120	9	−236	95	32	2.9688	CIS
46	EXP 62	+ − + + − +	1040	82	−72	308	−71	−233	277	32	8.6563	ACIS
47	EXP 14	− + + + − +	881	21	154	−272	4	28	−13	32	−0.4063	FCIS
48	EXP 46	+ + + + − +	1038	49	−137	−69	−17	53	−123	32	−3.8438	AFCIS
49	EXP 16	− − − − + +	897	16	8	−2	1195	−1810	107	32	3.3438	GS
50	EXP 48	+ − − − + +	1051	6	6	−1	−5	−1749	49	32	1.5313	AGS
51	EXP 00	− + − − + +	848	66	2	9	1032	−54	43	32	1.3438	FGS
52	EXP 32	+ + − − + +	1020	76	21	−248	253	−319	117	32	3.6563	AFGS
53	EXP 24	− − + − + +	1091	1	41	−40	91	92	−1169	32	−36.5313	CGS
54	EXP 56	+ − + − + +	1087	0	24	−10	23	193	−39	32	−1.2188	ACGS
55	EXP 08	− + + − + +	1024	152	−34	8	188	−80	3	32	0.0938	FCGS
56	EXP 40	+ + + − + +	1082	157	28	−291	203	−21	25	32	0.7813	AFCGS
57	EXP 20	− − − + + +	746	154	−10	−2	1	−1200	61	32	1.9063	IGS
58	EXP 52	+ − − + + +	808	172	10	19	−257	−779	−265	32	−8.2813	AIGS
59	EXP 04	− + − + + +	816	−4	−1	−17	30	−68	101	32	3.1563	FIGS
60	EXP 36	+ + − + + +	892	58	5	62	−299	15	59	32	1.8438	AFIGS
61	EXP 28	− − + + + +	1025	62	18	20	21	−258	421	32	13.1563	CIGS
62	EXP 60	+ − + + + +	1035	76	62	6	79	−329	83	32	2.5938	ACIGS
63	EXP 12	− + + + + +	932	10	14	44	−14	58	−71	32	−2.2188	FCIGS
64	EXP 44	+ + + + + +	991	59	49	35	−9	5	−53	32	−1.6563	AFCIGS

Appendix H: Difference Between Two Averages - Calculations for Estimate of Effect and Standard Error

Table 27. Summary of Estimated Effects of Conditions on the Ratio of Cargo Delivered

	RATIO ON TIME	RATIO DELIVERED
Average:		
	0.239219	0.567813

Two Factor Interaction Effects:	RATIO ON TIME	RATIO DELIVERED
AF	0.003438	0.006250
AC	0.015313	0.002500
AI	−0.002188	−0.000625
AG	0.007812	0.005625
AS	−0.001563	−0.000625
FC	0.002813	−0.005625
FI	0.000313	0.002500
FG	0.006562	0.017500
FS	0.002187	0.002500
CI	0.002188	−0.003750
CG	0.065938	0.057500
CS	0.007812	−0.003750
IG	0.000937	0.008125
IS	−0.000938	−0.005625
GS	0.010312	0.013125

Three Factor Interaction Effects:	RATIO ON TIME	RATIO DELIVERED
AFC	0.002187	0.004375
AFI	−0.000313	0.000000
AFG	0.003437	0.005000
AFS	0.000312	0.001250
ACI	0.001562	0.000000
ACG	0.002812	−0.011250
ACS	−0.001562	−0.001250
AIG	−0.002188	−0.000625
AIS	−0.000313	−0.000625
AGS	0.000937	0.000625
FCI	0.000313	−0.004375
FCG	0.002812	−0.004375
FCS	0.000937	−0.000625
FIG	0.000312	0.002500
FIS	−0.000313	0.001250
FGS	0.002187	0.001250
CIG	0.004687	0.006250
CIS	0.000312	−0.001250
CGS	0.002812	−0.015000
IGS	0.001562	0.001875

Main Effects:	RATIO ON TIME	RATIO DELIVERED
A	0.020313	0.019375
F	0.006562	0.016250
C	0.155938	0.338750
I	−0.001562	−0.001875
G	0.148437	0.334375
S	0.015312	0.024375

Four Factor Interaction Effects:	RATIO ON TIME	RATIO DELIVERED
AFCI	−0.000313	0.000625
AFCG	0.002187	0.003125
AFCS	0.001562	0.000625
AFIG	−0.000313	0.000000
AFIS	0.000312	−0.000000
AFGS	0.000312	0.002500
ACIG	0.001562	−0.000000
ACIS	0.000937	0.003750
ACGS	0.000937	0.000000
AIGS	−0.000313	−0.003125
FCIG	0.000313	−0.004375
FCIS	−0.000313	0.000625
FCGS	0.000937	−0.001875
FIGS	−0.000313	0.001250
CIGS	0.002812	0.006250

Five Factor Interaction Effects:	RATIO ON TIME	RATIO DELIVERED
AFCIG	−0.000313	0.000625
AFCIS	0.000312	−0.000625
AFCGS	0.001562	0.001875
AFIGS	0.000312	0.000000
ACIGS	0.000937	0.001250
FCIGS	−0.000313	0.000625

Six Factor Interaction Effect:	RATIO ON TIME	RATIO DELIVERED
AFCGIS	0.000312	−0.000625

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

	RATIO ON TIME	RATIO DELIVERED
Sum of squares:	0.000106	0.000603
Variance:	0.000003	0.000014
Est of Std Dev:	0.001592	0.003789

Table 28. Summary of Estimated Effects of Conditions on the Number of Hours Flown

	TOTAL FLIGHT HOURS	PRODUCTIVE FLIGHT HOURS
Average:		
	1576.766	295.719
Two Factor Interaction Effects:		
AF	-22.844	4.063
AC	-211.156	8.563
AI	-236.656	-10.500
AG	153.844	-4.000
AS	-23.969	-1.250
FC	17.094	-3.313
FI	-10.281	4.375
FG	-8.906	-5.000
FS	-13.219	0.250
CI	533.781	-18.000
CG	-960.469	-68.500
CS	-161.781	-5.500
IG	-559.719	-110.313
IS	-85.781	-4.063
GS	97.969	0.313
Three Factor Interaction Effects:		
AFC	43.594	2.813
AFI	-2.156	-2.125
AFG	-8.656	3.125
AFS	-11.094	-0.250
ACI	197.406	7.250
ACG	-224.969	-27.625
ACS	0.844	-2.000
AIG	-139.844	-7.313
AIS	-4.531	1.563
AGS	5.094	1.813
FCI	2.281	-4.625
FCG	-3.219	-2.875
FCS	21.594	-1.500
FIG	-25.969	5.438
FIS	-1.156	0.563
FGS	-2.656	-0.063
CIG	371.594	-1.688
CIS	81.156	3.688
CGS	-128.719	-15.063
IGS	-70.844	0.500

	TOTAL FLIGHT HOURS	PRODUCTIVE FLIGHT HOURS
Main Effects:		
A	403.031	36.563
F	-30.969	-4.063
C	-1039.781	152.938
I	-1118.156	-186.750
G	1144.719	199.125
S	182.281	10.250
Four Factor Interaction Effects:		
AFCI	-8.219	0.375
AFCG	20.656	1.750
AFCS	21.344	0.500
AFIG	-11.969	-2.063
AFIS	-4.531	0.438
AFGS	-6.656	2.188
ACIG	142.344	6.313
ACIS	19.781	4.313
ACGS	3.531	-0.063
AIGS	-31.469	-3.375
FCIG	26.469	-4.688
FCIS	-14.094	0.313
FCGS	-1.969	-0.438
FIGS	-11.844	1.500
CIGS	84.719	8.625
Five Factor Interaction Effects:		
AFCIG	14.594	0.313
AFCIS	-5.344	-1.313
AFCGS	5.906	1.813
AFIGS	-7.594	-0.375
ACIGS	26.219	0.750
FCIGS	18.344	0.125
Six Factor Interaction Effect:		
AFCGIS	15.469	-1.250

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

	TOTAL FLIGHT HOURS	PRODUCTIVE FLIGHT HOURS
Sum of squares:	311338.518	1395.336
Variance:	7412.822	33.222
Est of Std Dev:	86.098	5.764

Table 29. Summary of Estimated Effects of Conditions on the Number of Sorties Flown

	TOTAL SORTIES	PRODUCTIVE SORTIES
Average:		
	4039.906	758.828
Two Factor Interaction Effects:		
AF	-68.188	7.594
AC	-523.188	8.094
AI	-310.125	-3.594
AG	356.688	5.531
AS	-67.125	-2.781
FC	68.313	-17.969
FI	-47.500	7.719
FG	-61.813	-10.281
FS	-56.000	1.781
CI	598.500	77.344
CG	-2001.938	-141.656
CS	-390.000	-13.719
IG	-489.250	-111.219
IS	-72.688	-7.656
GS	162.125	3.344
Three Factor Interaction Effects:		
AFC	108.875	5.219
AFI	-26.563	-2.344
AFG	-36.000	5.031
AFS	-33.188	1.594
ACI	345.438	15.781
ACG	-537.375	-46.844
ACS	6.813	-2.656
AIG	-234.063	-11.656
AIS	-25.250	1.906
AGS	-6.813	1.531
FCI	9.813	-16.406
FCG	10.125	-14.656
FCS	60.938	-2.844
FIG	-94.188	8.906
FIS	-5.000	1.344
FGS	-17.938	1.344
CIG	301.188	-61.844
CIS	58.500	2.969
CGS	-238.563	-36.531
IGS	-91.250	1.906

	TOTAL SORTIES	PRODUCTIVE SORTIES
Main Effects:		
A	956.125	69.094
F	-138.875	-9.719
C	-2453.875	340.531
I	-316.938	10.094
G	2333.250	366.844
S	424.688	30.281
Four Factor Interaction Effects:		
AFCI	15.375	2.406
AFCG	62.563	2.531
AFCS	54.875	1.344
AFIG	-41.875	-3.156
AFIS	-19.688	1.531
AFGS	-28.750	3.656
ACIG	211.250	-1.656
ACIS	45.313	8.656
ACGS	20.875	-1.219
AIGS	-94.688	-8.281
FCIG	78.375	-18.344
FCIS	-34.188	-0.406
FCGS	2.750	0.094
FIGS	-47.438	3.156
CIGS	115.438	13.156
Five Factor Interaction Effects:		
AFCIG	64.063	1.969
AFCIS	8.000	-3.844
AFCGS	28.813	0.781
AFIGS	-20.500	1.844
ACIGS	81.125	2.594
FCIGS	59.625	-2.219
Six Factor Interaction Effect:		
AFCGIS	51.188	-1.656

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

	TOTAL SORTIES	PRODUCTIVE SORTIES
Sum of squares	758357.117	9143.674
Variance:	18056.122	217.707
Est of Std Dev:	134.373	14.755

Appendix I: Yate's Algorithm - Calculations for Estimate of Effect for Transformed Results

Table 30A. Yate's algorithm, Results for Ratio On Time – Transformed to Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio On Time	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	-	-	-	-	-	-	-2.120264	-4.24	-8.48	-14.83	-29.66	-49.97	-98.27	64	-1.535428	average
2	EXP 51	+	-	-	-	-	-	-2.120264	-4.24	-6.35	-14.83	-20.30	-48.30	2.22	32	0.069347	A
3	EXP 03	-	+	-	-	-	-	-2.120264	-3.17	-8.48	-10.12	-29.27	1.26	0.63	32	0.019679	F
4	EXP 35	+	+	-	-	-	-	-2.120264	-3.17	-6.35	-10.19	-19.03	0.96	0.29	32	0.008980	AF
5	EXP 27	-	-	+	-	-	-	-1.660731	-4.24	-6.49	-14.54	0.59	0.22	20.74	32	0.647986	C
6	EXP 59	+	-	+	-	-	-	-1.514128	-4.24	-3.82	-14.73	0.67	0.41	1.44	32	0.045037	AC
7	EXP 11	-	+	+	-	-	-	-1.660731	-3.17	-6.59	-9.47	0.37	0.17	0.05	32	0.001497	FC
8	EXP 43	+	+	+	-	-	-	-1.514128	-3.17	-3.60	-9.56	0.59	0.12	0.10	32	0.002996	AFC
9	EXP 23	-	-	-	+	-	-	-2.120264	-3.27	-8.48	0.29	0.00	10.12	-0.36	32	-0.011130	I
10	EXP 55	+	-	-	+	-	-	-2.120264	-3.22	-6.06	0.29	0.22	10.61	-0.31	32	-0.009631	AI
11	EXP 07	-	+	-	+	-	-	-2.120264	-1.84	-8.48	0.40	0.00	0.85	0.03	32	0.000950	FI
12	EXP 39	+	+	-	+	-	-	-2.120264	-1.79	-6.25	0.27	0.41	0.59	-0.02	32	-0.000638	AFI
13	EXP 31	-	-	+	+	-	-	-1.660731	-3.32	-6.15	0.18	0.00	0.02	0.22	32	0.006768	CI
14	EXP 63	+	-	+	+	-	-	-1.514128	-3.27	-3.31	0.19	0.17	0.03	0.26	32	0.008267	ACI
15	EXP 15	-	+	+	+	-	-	-1.660731	-1.84	-6.34	0.39	0.00	-0.03	0.02	32	0.000522	FCI
16	EXP 47	+	+	+	+	-	-	-1.514128	-1.76	-3.22	0.20	0.12	0.13	-0.03	32	-0.001066	AFCI
17	EXP 17	-	-	-	-	+	-	-1.660731	-4.24	0.00	0.00	4.26	-0.07	19.60	32	0.612359	G
18	EXP 49	+	-	-	-	+	-	-1.609438	-4.24	0.29	0.00	5.86	-0.28	0.30	32	0.009410	AG
19	EXP 01	-	+	-	-	+	-	1.660731	-3.03	0.00	0.10	4.65	-0.13	0.63	32	0.019679	FG
20	EXP 33	+	+	-	-	+	-	-1.5606[illegible]8	-3.03	0.29	0.12	5.96	-0.18	0.29	32	0.008980	AFG
21	EXP 25	-	-	+	-	+	-	-0.967584	-4.24	0.15	0.00	0.59	0.03	2.90	32	0.090673	CG
22	EXP 57	+	-	+	-	+	-	-0.867501	4.24	0.25	0.00	0.26	0.00	-0.48	32	-0.014899	ACG
23	EXP 09	-	+	+	-	+	-	-0.967584	-3.12	0.05	0.20	0.37	-0.02	0.05	32	0.001497	FCG
24	EXP 41	+	+	+	-	+	-	-0.820981	-3.12	0.22	0.21	0.22	0.00	0.10	32	0.002996	AFCG
25	EXP 21	-	-	-	+	+	-	-1.660731	-3.12	0.00	0.00	0.00	0.13	0.02	32	0.000525	IG
26	EXP 53	+	-	-	+	+	-	-1.660731	-3.03	0.18	0.00	0.02	0.09	-0.33	32	-0.010174	AIG
27	EXP 05	-	+	-	+	+	-	-1.660731	-1.71	0.00	0.10	0.00	0.07	0.03	32	0.000950	FIG
28	EXP 37	+	+	-	+	+	-	-1.609438	1.60	0.19	0.07	0.03	0.19	-0.02	32	-0.000638	AFIG
29	EXP 29	-	-	+	+	+	-	-0.967584	-3.22	0.19	0.00	0.00	0.02	0.59	32	0.018423	CIG
30	EXP 61	+	-	+	+	+	-	-0.867501	3.12	0.20	0.00	-0.03	-0.01	0.25	32	0.007724	ACIG
31	EXP 13	-	+	+	+	+	-	-0.941609	1.67	0.00	0.06	0.00	-0.03	0.02	32	0.000522	FCIG
32	EXP 45	+	+	+	+	+	-	-0.820981	1.56	0.20	0.06	0.13	-0.01	-0.03	32	-0.001066	AFCIG

Table 30B. Yate's algorithm, Results for Ratio On Time – Transformed to Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Ratio On Time	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
33	EXP 18	–	–	–	–	–	+	–2.120264	0.00	0.00	2.13	0.00	9.36	1.66	32	0.052023	S
34	EXP 50	+	–	–	–	–	+	–2.120264	0.00	0.00	2.13	–0.07	10.24	–0.29	32	–0.009184	AS
35	EXP 02	–	+	–	–	–	+	–2.120264	0.15	0.00	2.87	–0.19	0.08	0.19	32	0.005985	FS
36	EXP 34	+	+	–	–	–	+	–2.120264	0.15	0.00	2.99	–0.10	0.22	–0.05	32	–0.001467	AFS
37	EXP 26	–	–	+	–	–	+	–1.560648	0.00	0.05	2.42	0.00	0.22	0.49	32	0.015203	CS
38	EXP 58	+	–	+	–	–	+	–1.469676	0.00	0.05	2.23	–0.13	0.41	–0.26	32	–0.008159	ACS
39	EXP 10	–	+	+	–	–	+	–1.560648	0.15	0.05	2.84	0.01	0.17	0.01	32	0.000314	FCS
40	EXP 42	+	+	+	–	–	+	–1.469676	0.15	0.07	3.12	–0.19	0.12	0.16	32	0.005059	AFCS
41	EXP 22	–	–	–	+	–	+	–2.120264	0.05	0.00	0.29	0.00	1.60	–0.21	32	–0.006498	IS
42	EXP 54	+	–	–	+	–	+	–2.120264	0.10	0.00	0.29	0.03	1.30	–0.06	32	–0.001753	AIS
43	EXP 06	–	+	–	+	–	+	–2.120264	0.10	0.00	0.10	0.00	–0.32	–0.03	32	–0.000830	FIS
44	EXP 38	+	+	–	+	–	+	–2.120264	0.15	0.00	0.17	0.00	–0.16	0.03	32	0.000829	AFIS
45	EXP 30	–	–	+	+	–	+	–1.609438	0.00	0.09	0.18	0.00	0.02	–0.04	32	–0.001111	CIS
46	EXP 62	+	–	+	+	–	+	–1.514128	0.05	0.11	0.19	–0.02	0.03	0.12	32	0.003635	ACIS
47	EXP 14	–	+	+	+	–	+	–1.609438	0.10	0.10	0.02	0.00	–0.03	–0.03	32	–0.000945	FCIS
48	EXP 46	+	+	+	+	–	+	–1.514128	0.12	0.11	0.20	0.00	0.13	0.02	32	0.000714	AFCIS
49	EXP 16	–	–	–	–	+	+	–1.609438	0.00	0.00	0.00	0.00	–0.07	0.88	32	0.027544	GS
50	EXP 48	+	–	–	–	+	+	–1.514128	0.00	0.00	0.00	0.13	0.09	0.13	32	0.004182	AGS
51	EXP 00	–	+	–	–	+	+	–1.560648	0.09	0.00	–0.00	–0.19	–0.13	0.19	32	0.005985	FGS
52	EXP 32	+	+	–	–	+	+	–1.469676	0.09	0.00	0.02	0.28	–0.20	–0.05	32	–0.001467	AFGS
53	EXP 24	–	–	+	–	+	+	–0.891598	0.00	0.05	0.00	0.00	0.03	–0.30	32	–0.009276	CGS
54	EXP 56	+	–	+	–	+	+	–0.820981	0.00	0.05	0.00	0.07	0.00	0.17	32	0.005206	ACGS
55	EXP 08	–	+	+	–	+	+	–0.867501	0.10	0.05	0.02	0.01	–0.02	0.01	32	0.000314	FCGS
56	EXP 40	+	+	+	–	+	+	–0.733969	0.10	0.02	0.01	0.18	0.00	0.16	32	0.005059	AFCGS
57	EXP 20	–	–	–	+	+	+	–1.609438	0.10	0.00	0.00	0.00	0.13	0.17	32	0.005157	IGS
58	EXP 52	+	–	–	+	+	+	–1.609438	0.09	0.00	0.00	0.02	0.46	–0.07	32	–0.002295	AIGS
59	EXP 04	–	+	–	+	+	+	–1.560648	0.07	0.00	–0.00	0.00	0.07	–0.03	32	–0.000830	FIGS
60	EXP 36	+	+	–	+	+	+	–1.560648	0.13	0.00	–0.03	–0.01	0.17	0.03	32	0.000829	AFIGS
61	EXP 28	–	–	+	+	+	+	–0.867501	0.00	–0.00	0.00	0.00	0.02	0.34	32	0.010545	CIGS
62	EXP 60	+	–	+	+	+	+	–0.798508	0.00	0.06	0.00	–0.03	–0.01	0.10	32	0.003093	ACIGS
63	EXP 12	–	+	+	+	+	+	–0.843970	0.07	0.00	0.07	0.00	–0.03	–0.03	32	–0.000945	FCIGS
64	EXP 44	+	+	+	+	+	+	–0.713350	0.13	0.06	0.06	–0.01	–0.01	0.02	32	0.000714	AFCIGS

Table 31A Yate's algorithm, Results for Ratio Delivered - Transformed to Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Ratio Delivered	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	-	-	-	-	-	-	-1.347074	-2.69	-5.39	-7.91	-15.86	-21.91	-42.50	64	-0.664018	average
2	EXP 51	+	-	-	-	-	-	-1.347074	-2.69	-2.52	-7.95	-8.05	-20.58	1.05	32	0.032740	A
3	EXP 03	-	+	-	-	-	-	-1.347074	-1.25	-5.39	-3.09	-15.53	0.56	0.81	32	0.025351	F
4	EXP 35	+	+	-	-	-	-	-1.347074	-1.27	-2.56	-2.96	-5.06	0.49	0.23	32	0.007268	AF
5	EXP 27	-	-	+	-	-	-	-0.653926	-2.69	-2.76	-7.64	0.23	0.35	20.60	32	0.643881	C
6	EXP 59	+	-	+	-	-	-	-0.597837	-2.69	-0.33	-7.89	0.33	0.46	0.05	32	0.001407	AC
7	EXP 11	-	+	+	-	-	-	-0.673345	-1.27	-2.66	-2.53	0.18	0.10	-0.48	32	-0.015130	FC
8	EXP 43	+	+	+	-	-	-	-0.597837	-1.29	-0.30	-2.53	0.31	0.13	0.16	32	0.005060	AFC
9	EXP 23	-	-	-	+	-	-	-1.347074	-1.43	-5.39	0.13	-0.04	10.48	-0.16	32	-0.005024	I
10	EXP 55	+	-	-	+	-	-	-1.347074	-1.33	-2.25	0.09	0.39	10.13	-0.02	32	-0.000609	AI
11	EXP 07	-	+	-	+	-	-	-1.347074	-0.20	-5.39	0.14	0.00	0.05	0.17	32	0.005321	FI
12	EXP 39	+	+	-	+	-	-	-1.347074	-0.13	-2.50	0.19	0.46	-0.00	-0.01	32	-0.000456	AFI
13	EXP 31	-	-	+	+	-	-	-0.653926	-1.43	-2.27	0.07	0.04	-0.24	-0.27	32	-0.008462	CI
14	EXP 63	+	-	+	+	-	-	-0.616186	-1.23	-0.28	0.11	0.06	-0.25	0.01	32	0.000229	ACI
15	EXP 15	-	+	+	+	-	-	-0.673345	-0.17	-2.31	0.19	0.00	0.08	-0.24	32	-0.007413	FCI
16	EXP 47	+	+	+	+	-	-	-0.616186	-0.13	-0.22	0.12	0.13	0.08	0.04	32	0.001112	AFCI
17	EXP 17	-	-	-	-	+	-	-0.733969	-2.69	0.00	-0.02	5.69	0.09	20.28	32	0.633737	G
18	EXP 49	+	-	-	-	+	-	-0.693147	-2.69	0.13	-0.02	4.78	-0.25	0.23	32	0.007187	AG
19	EXP 01	-	+	-	-	+	-	-0.693147	-1.12	0.00	0.16	6.02	0.01	0.89	32	0.027778	FG
20	EXP 33	+	+	-	-	+	-	-0.634878	-1.12	0.09	0.23	4.10	-0.03	0.15	32	0.004841	AFG
21	EXP 25	-	-	+	-	+	-	-0.105361	-2.69	0.10	0.00	0.23	0.06	-2.83	32	-0.088493	CG
22	EXP 57	+	-	+	-	+	-	-0.094311	-2.69	0.04	0.00	-0.18	0.11	-0.77	32	-0.024146	ACG
23	EXP 09	-	+	+	-	+	-	-0.083382	-1.25	0.16	0.18	0.18	-0.01	-0.41	32	-0.012702	FCG
24	EXP 41	+	+	+	-	+	-	-0.051293	-1.25	0.03	0.28	-0.18	-0.00	0.08	32	0.002633	AFCG
25	EXP 21	-	-	-	+	+	-	-0.755023	-1.20	0.00	0.02	-0.04	-0.10	0.42	32	0.013172	IG
26	EXP 53	+	-	-	+	+	-	-0.673345	-1.07	0.07	0.02	-0.20	-0.17	-0.03	32	-0.000940	AIG
27	EXP 05	-	+	-	+	+	-	-0.653926	-0.16	0.00	0.04	0.00	-0.10	0.17	32	0.005321	FIG
28	EXP 37	+	+	-	+	+	-	-0.579818	-0.10	0.11	0.02	-0.25	0.11	-0.01	32	-0.000456	AFIG
29	EXP 29	-	-	+	+	+	-	-0.083382	-1.27	0.16	0.00	0.04	-0.13	0.31	32	0.009734	CIG
30	EXP 61	+	-	+	+	+	-	-0.083382	-1.04	0.03	0.00	0.04	-0.11	-0.00	32	-0.000102	ACIG
31	EXP 13	-	+	+	+	+	-	-0.083382	-0.13	0.09	0.07	0.00	0.04	-0.24	32	-0.007413	FCIG
32	EXP 45	+	+	+	+	+	-	-0.051293	-0.08	0.03	0.07	0.08	-0.00	0.04	32	0.001112	AFCIG

Table 31B. Yate's algorithm, Results for Ratio Delivered - Transformed to Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Ratio Delivered	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	-	-	-	-	-	+	-1.347074	0.00	0.00	2.87	-0.04	9.81	1.33	32	0.041477	S
34	EXP 50	+	-	-	-	-	+	-1.347074	0.00	-0.02	2.83	0.13	10.47	-0.07	32	-0.002047	AS
35	EXP 02	-	+	-	-	-	+	-1.347074	0.06	0.00	2.42	-0.25	0.10	0.11	32	0.003353	FS
36	EXP 34	+	+	-	-	-	+	-1.347074	0.06	-0.02	2.36	0.00	0.13	0.03	32	0.000903	AFS
37	EXP 26	-	-	+	-	-	+	-0.579818	0.00	0.10	3.14	-0.04	0.43	-0.35	32	-0.010836	CS
38	EXP 58	+	-	+	-	-	+	-0.544727	0.00	0.06	2.88	0.05	0.46	-0.05	32	-0.001521	ACS
39	EXP 10	-	+	+	-	-	+	-0.579818	0.04	0.19	2.01	0.04	0.02	-0.01	32	-0.000413	FCS
40	EXP 42	+	+	+	-	-	+	-0.544727	0.06	0.03	2.09	-0.07	0.13	-0.00	32	-0.000070	AFCS
41	EXP 22	-	-	-	+	-	+	-1.347074	0.04	0.00	0.13	-0.00	-0.91	-0.34	32	-0.010601	IS
42	EXP 54	+	-	-	+	-	+	-1.347074	0.06	0.00	0.09	0.06	-1.92	-0.04	32	-0.001168	AIS
43	EXP 06	-	+	-	+	-	+	-1.347074	0.01	0.00	-0.06	0.00	-0.41	0.05	32	0.001407	FIS
44	EXP 38	+	+	-	+	-	+	-1.347074	0.03	0.00	-0.12	0.11	-0.37	0.01	32	0.000417	AFIS
45	EXP 30	-	-	+	+	-	+	-0.653926	0.06	0.12	0.07	0.00	-0.16	-0.08	32	-0.002410	CIS
46	EXP 62	+	-	+	+	-	+	-0.597837	0.07	0.05	0.11	-0.01	-0.25	0.22	32	0.006757	ACIS
47	EXP 14	-	+	+	+	-	+	-0.653926	0.00	0.23	-0.13	0.00	0.00	0.02	32	0.000615	FCIS
48	EXP 46	+	+	+	+	-	+	-0.597837	0.03	0.05	-0.06	-0.00	0.06	-0.04	32	-0.001142	AFCIS
49	EXP 16	-	-	-	-	+	+	-0.634678	0.00	0.00	-0.02	-0.04	0.16	0.67	32	0.020854	GS
50	EXP 48	+	-	-	-	+	+	-0.562119	0.00	0.02	-0.02	-0.06	0.26	0.02	32	0.000711	AGS
51	EXP 00	-	+	-	-	+	+	-0.579818	0.04	0.00	-0.03	-0.25	0.08	0.03	32	0.000926	FGS
52	EXP 32	+	+	-	-	+	+	-0.494296	0.04	0.02	-0.16	0.08	-0.11	0.11	32	0.003331	AFGS
53	EXP 24	-	-	+	-	+	+	-0.072571	0.00	0.02	0.00	-0.04	0.06	-1.01	32	-0.031459	CGS
54	EXP 56	+	-	+	-	+	+	-0.083382	0.00	0.02	0.00	-0.07	0.11	0.04	32	0.001238	ACGS
55	EXP 08	-	+	+	-	+	+	-0.072571	0.06	-0.01	-0.07	0.04	-0.01	-0.09	32	-0.002840	FCGS
56	EXP 40	+	+	+	-	+	+	-0.030459	0.06	0.03	-0.18	0.07	-0.00	0.08	32	0.002357	AFCGS
57	EXP 20	-	-	-	+	+	+	-0.653926	0.07	0.00	0.02	-0.00	-0.02	0.10	32	0.003007	IGS
58	EXP 52	+	-	-	+	+	+	-0.616186	0.09	0.00	0.02	-0.13	0.33	-0.19	32	-0.006087	AIGS
59	EXP 04	-	+	-	+	+	+	-0.544727	-0.01	0.00	0.00	0.00	-0.03	0.05	32	0.001407	FIGS
60	EXP 36	+	+	-	+	+	+	-0.494296	0.04	0.00	0.04	-0.11	0.03	0.01	32	0.000417	AFIGS
61	EXP 28	-	-	+	+	+	+	-0.061875	0.04	0.01	0.00	0.00	-0.13	0.36	32	0.011198	CIGS
62	EXP 60	+	-	+	+	+	+	-0.072571	0.05	0.05	0.00	0.04	-0.11	0.06	32	0.001839	ACIGS
63	EXP 12	-	+	+	+	+	+	-0.061875	-0.01	0.01	0.04	0.00	0.04	0.02	32	0.000615	FCIGS
64	EXP 44	+	+	+	+	+	+	-0.020203	0.04	0.05	0.04	-0.00	-0.00	-0.04	32	-0.001142	AFCIGS

Table 32A. Yate's algorithm, Results for Total Flight Hours – Transformed To Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Total Flight Hours	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
1	EXP 19	–	–	–	–	–	–	7.008505	14.37	28.75	56.81	109.02	227.82	458.42	64	7.163	average
2	EXP 51	+	–	–	–	–	–	7.364547	14.37	28.06	52.21	118.80	230.60	6.86	32	0.214	A
3	EXP 03	–	+	–	–	–	–	7.027315	14.06	25.78	62.45	110.48	3.93	-0.71	32	-0.022	F
4	EXP 35	+	+	–	–	–	–	7.344719	14.01	26.43	56.35	120.12	2.93	-0.19	32	-0.006	AF
5	EXP 27	–	–	+	–	–	–	6.866933	12.91	33.08	57.47	2.18	-0.26	-16.02	32	-0.501	C
6	EXP 59	+	–	+	–	–	–	7.188413	12.87	29.36	53.02	1.75	-0.45	-0.70	32	-0.022	AC
7	EXP 11	–	+	+	–	–	–	6.844815	13.22	29.81	63.23	1.65	-0.05	0.16	32	0.005	FC
8	EXP 43	+	+	+	–	–	–	7.181622	13.21	26.54	56.89	1.28	-0.14	0.81	32	0.025	AFC
9	EXP 23	–	–	–	+	–	–	6.386879	16.53	29.14	1.31	-0.09	-7.01	-21.47	32	-0.671	I
10	EXP 55	+	–	–	+	–	–	6.520621	16.55	28.33	0.87	-0.17	-9.01	-1.45	32	-0.045	AI
11	EXP 07	–	+	–	+	–	–	6.381818	14.70	26.40	1.07	-0.17	-0.46	-0.27	32	-0.008	FI
12	EXP 39	+	+	–	+	–	–	6.490724	14.66	26.62	0.67	-0.28	-0.24	-0.07	32	-0.002	AFI
13	EXP 31	–	–	+	+	–	–	6.455199	14.94	33.91	0.86	-0.06	-0.09	3.59	32	0.112	CI
14	EXP 63	+	–	+	+	–	–	6.763885	14.87	29.32	0.79	0.01	0.25	1.73	32	0.054	ACI
15	EXP 15	–	+	+	+	–	–	6.448889	13.31	30.36	0.91	-0.08	0.24	-0.12	32	-0.004	FCI
16	EXP 47	+	+	+	+	–	–	6.765039	13.23	26.54	0.38	-0.06	0.57	-0.04	32	-0.001	AFCI
17	EXP 17	–	–	–	–	+	–	6.048149	14.67	0.67	-0.05	-0.03	-10.69	19.41	32	0.607	G
18	EXP 49	+	–	–	–	+	–	6.482809	14.47	0.64	-0.04	-6.98	-10.78	-0.79	32	-0.025	AG
19	EXP 01	–	+	–	–	+	–	6.074026	14.13	0.24	-0.02	-0.59	-0.84	-0.19	32	-0.006	FG
20	EXP 33	+	+	–	–	+	–	6.478036	14.20	0.62	-0.15	-8.41	-0.61	0.09	32	0.003	AFG
21	EXP 25	–	–	+	–	+	–	7.302496	13.19	0.84	-0.14	0.35	-0.12	-14.77	32	-0.462	CG
22	EXP 57	+	–	+	–	+	–	7.400621	13.21	0.24	-0.03	-0.81	-0.15	-1.94	32	-0.061	ACG
23	EXP 09	–	+	+	–	+	–	7.261225	13.33	0.44	-0.01	0.27	0.02	-0.21	32	-0.007	FCG
24	EXP 41	+	+	+	–	+	–	7.399398	13.29	0.23	-0.27	-0.51	-0.09	0.29	32	0.009	AFCG
25	EXP 21	–	–	–	+	+	–	7.346655	16.95	0.44	-0.04	-0.02	1.79	-3.39	32	-0.106	IG
26	EXP 53	+	–	–	+	+	–	7.591862	16.96	0.42	-0.02	-0.07	1.80	-0.41	32	-0.013	AIG
27	EXP 05	–	+	–	+	+	–	7.335634	14.66	0.25	0.01	0.20	0.81	-0.52	32	-0.016	FIG
28	EXP 37	+	+	–	+	+	–	7.532088	14.65	0.54	0.00	0.04	0.91	-0.18	32	-0.006	AFIG
29	EXP 29	–	–	+	+	+	–	6.609349	15.26	0.73	-0.05	0.07	0.13	-1.13	32	-0.035	CIG
30	EXP 61	+	–	+	+	+	–	6.700731	15.09	0.17	-0.02	0.17	-0.25	0.27	32	0.008	ACIG
31	EXP 13	–	+	+	+	+	–	6.545350	13.32	0.17	0.03	0.19	0.03	0.38	32	0.012	FCIG
32	EXP 45	+	+	+	+	+	–	6.687109	13.22	0.21	-0.09	0.38	-0.07	0.42	32	0.013	AFCIG

Table 32B. Yate's algorithm, Results for Total Flight Hours - Transformed To Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Total Flight Hours	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	-	-	-	-	-	+	7.191429	0.36	-0.00	-0.68	-4.59	9.78	2.79	32	0.087	S
34	EXP 50	+	-	-	-	-	+	7.478170	0.32	-0.05	0.65	-6.10	9.64	-1.00	32	-0.031	AS
35	EXP 02	-	+	-	-	-	+	7.156177	0.32	-0.03	-3.72	-4.45	-0.43	-0.19	32	-0.006	FS
36	EXP 34	+	+	-	-	-	+	7.310550	0.32	-0.01	-3.26	-6.33	-0.37	-0.09	32	-0.003	AFS
37	EXP 26	-	-	+	-	-	+	6.981006	0.13	0.02	-0.81	-0.44	-0.08	-1.99	32	-0.062	CS
38	EXP 58	+	-	+	-	-	+	7.153052	0.11	-0.04	0.21	-0.40	-0.11	0.23	32	0.007	ACS
39	EXP 10	-	+	+	-	-	+	6.972606	0.31	-0.07	-4.60	-0.08	0.07	0.33	32	0.010	FCS
40	EXP 42	+	+	+	-	-	+	7.222566	0.32	-0.08	-3.82	-0.53	0.02	0.33	32	0.010	AFCS
41	EXP 22	-	-	-	+	-	+	6.533789	0.43	-0.20	-0.04	0.01	-6.95	-0.09	32	-0.003	IS
42	EXP 54	+	-	-	+	-	+	8.658011	0.40	0.06	0.38	-0.13	-7.82	0.24	32	0.007	AIS
43	EXP 06	-	+	-	+	-	+	6.543912	0.10	0.02	-0.60	0.11	-1.16	-0.03	32	-0.001	FIS
44	EXP 38	+	+	-	+	-	+	6.665684	0.14	-0.05	-0.21	-0.27	-0.79	-0.10	32	-0.003	AFIS
45	EXP 30	-	-	+	+	-	+	6.525030	0.25	0.00	-0.02	0.03	-0.05	0.01	32	0.000	CIS
46	EXP 62	+	-	+	+	-	+	6.805723	0.20	-0.01	0.29	-0.01	-0.16	0.10	32	0.003	ACIS
47	EXP 14	-	+	+	+	-	+	6.513230	0.09	-0.17	-0.56	0.03	0.10	-0.39	32	-0.012	FCIS
48	EXP 46	+	+	+	+	-	+	6.771936	0.14	-0.11	0.05	-0.12	0.19	-0.10	32	-0.003	AFCIS
49	EXP 16	-	-	-	-	+	+	8.283494	0.29	-0.04	-0.05	1.34	-1.50	-0.14	32	-0.004	GS
50	EXP 48	+	-	-	-	+	+	8.669743	0.15	-0.00	0.03	0.46	-1.89	0.06	32	0.002	AGS
51	EXP 00	-	+	-	-	+	+	8.306225	0.17	-0.02	-0.06	1.02	0.04	-0.03	32	-0.001	FGS
52	EXP 32	+	+	-	-	+	+	8.651549	0.25	0.01	-0.01	0.78	-0.45	-0.05	32	-0.002	AFGS
53	EXP 24	-	-	+	-	+	+	7.305188	0.12	-0.03	0.26	0.42	-0.14	-0.87	32	-0.027	CGS
54	EXP 56	+	-	+	-	+	+	7.358194	0.12	0.04	-0.06	0.39	-0.38	0.37	32	0.012	ACGS
55	EXP 08	-	+	+	-	+	+	7.265430	0.28	-0.05	-0.02	0.31	-0.03	-0.10	32	-0.003	FCGS
56	EXP 40	+	+	+	-	+	+	7.387090	0.26	0.05	0.06	0.60	-0.15	0.08	32	0.003	AFCGS
57	EXP 20	-	-	-	+	+	+	7.544332	0.39	-0.13	0.03	0.08	-0.88	-0.38	32	-0.012	IGS
58	EXP 52	+	-	-	+	+	+	7.716461	0.35	0.08	0.03	0.06	-0.25	-0.50	32	-0.015	AIGS
59	EXP 04	-	+	-	+	+	+	7.550661	0.05	-0.00	0.07	-0.33	-0.02	-0.24	32	-0.008	FIGS
60	EXP 36	+	+	-	+	+	+	7.544332	0.12	-0.02	0.10	0.08	0.29	-0.11	32	-0.003	AFIGS
61	EXP 28	-	-	+	+	+	+	6.830683	0.17	-0.04	0.21	-0.00	-0.02	0.64	32	0.020	CIGS
62	EXP 60	+	-	+	+	+	+	6.890842	-0.01	0.07	-0.02	0.03	0.40	0.31	32	0.010	ACIGS
63	EXP 12	-	+	+	+	+	+	6.532334	0.06	-0.18	0.11	-0.23	0.03	0.42	32	0.013	FCIGS
64	EXP 44	+	+	+	+	+	+	6.683361	0.15	0.09	0.27	0.16	0.39	0.36	32	0.011	AFCIGS

Table 33A. Yate's algorithm, Results for Total Sorties Flown - Transformed to Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Total Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
1	EXP 19	−	−	−	−	−	−	7.821643	15.98	31.96	62.95	126.47	260.95	524.60	64	8.197	average
2	EXP 51	+	−	−	−	−	−	8.163086	15.98	30.99	63.51	134.49	263.64	6.56	32	0.205	A
3	EXP 03	−	+	−	−	−	−	7.841493	15.52	31.73	67.56	127.94	3.77	−1.00	32	−0.031	F
4	EXP 35	+	+	−	−	−	−	8.138273	15.46	31.78	66.93	135.70	2.79	−0.20	32	−0.006	AF
5	EXP 27	−	−	+	−	−	−	7.616776	15.89	35.60	63.67	1.94	−0.35	−16.83	32	−0.526	C
6	EXP 59	+	−	+	−	−	−	7.905442	15.84	31.96	64.27	1.83	−0.86	−1.46	32	−0.046	AC
7	EXP 11	−	+	+	−	−	−	7.590852	15.89	34.86	68.26	1.44	−0.07	0.22	32	0.007	FC
8	EXP 43	+	+	+	−	−	−	7.873598	15.89	32.07	67.44	1.35	−0.13	0.70	32	0.022	AFC
9	EXP 23	−	−	−	+	−	−	7.882315	17.79	32.41	1.21	−0.11	−7.34	−0.29	32	−0.009	I
10	EXP 55	+	−	−	+	−	−	8.004366	17.80	31.26	0.73	−0.23	−9.49	−1.42	32	−0.044	AI
11	EXP 07	−	+	−	+	−	−	7.870166	16.01	32.38	1.10	−0.26	−0.82	−0.21	32	−0.007	FI
12	EXP 39	+	+	−	+	−	−	7.974533	15.95	31.89	0.73	−0.39	−0.63	−0.10	32	−0.003	AFI
13	EXP 31	−	−	+	+	−	−	7.822044	17.47	36.37	0.74	−0.07	−0.09	3.65	32	0.114	CI
14	EXP 63	+	−	+	+	−	−	8.072779	17.38	31.90	0.70	−0.00	0.30	1.49	32	0.046	ACI
15	EXP 15	−	+	+	+	−	−	7.817625	16.08	35.41	0.94	−0.04	0.20	−0.17	32	−0.005	FCI
16	EXP 47	+	+	+	+	−	−	8.070281	15.99	32.03	0.41	−0.09	0.51	−0.03	32	−0.001	AFCI
17	EXP 17	−	−	−	−	+	−	8.865613	16.35	0.64	−0.06	−0.93	−0.07	15.79	32	0.493	G
18	EXP 49	+	−	−	−	+	−	9.128154	16.07	0.57	−0.05	−6.41	−0.23	−0.20	32	−0.006	AG
19	EXP 01	−	+	−	−	+	−	8.681351	15.60	0.23	−0.05	−1.64	−0.85	−0.25	32	−0.008	FG
20	EXP 33	+	+	−	−	+	−	9.120416	15.66	0.50	−0.18	−7.85	−0.57	0.02	32	0.001	AFG
21	EXP 25	−	−	+	−	+	−	7.965893	16.18	0.90	−0.23	0.21	−0.12	−11.70	32	−0.365	CG
22	EXP 57	+	−	+	−	+	−	8.045588	16.19	0.20	−0.03	−1.03	−0.09	−2.17	32	−0.068	ACG
23	EXP 09	−	+	+	−	+	−	7.916443	15.97	0.53	−0.05	0.15	0.00	−0.30	32	−0.009	FCG
24	EXP 41	+	+	+	−	+	−	8.035279	15.92	0.20	−0.34	−0.78	−0.11	0.25	32	0.008	AFCG
25	EXP 21	−	−	−	+	+	−	8.592301	18.19	0.38	−0.05	−0.02	1.88	−2.61	32	−0.082	IG
26	EXP 53	+	−	−	+	+	−	8.880307	18.17	0.36	−0.02	−0.07	1.77	−0.38	32	−0.012	AIG
27	EXP 05	−	+	−	+	+	−	8.570734	15.97	0.26	0.02	0.27	0.72	−0.62	32	−0.019	FIG
28	EXP 37	+	+	−	+	+	−	8.812397	15.93	0.43	−0.02	0.03	0.77	−0.16	32	−0.005	AFIG
29	EXP 29	−	−	+	+	+	−	7.998671	17.80	0.81	−0.02	0.06	0.15	0.24	32	0.008	CIG
30	EXP 61	+	−	+	+	+	−	8.084562	17.61	0.13	−0.02	0.14	−0.32	0.42	32	0.013	ACIG
31	EXP 13	−	+	+	+	+	−	7.937732	16.09	0.26	0.01	0.17	−0.01	0.44	32	0.014	FCIG
32	EXP 45	+	+	+	+	+	−	8.052933	15.94	0.15	−0.09	0.34	−0.02	0.43	32	0.013	AFCIG

Table 33B Yate's algorithm, Results for Total Sorties Flown – Transformed to Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Total Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	–	–	–	–	–	+	8.052615	0.34	–0.00	–0.98	0.56	8.02	2.69	32	0.084	S
34	EXP 50	+	–	–	–	–	+	8.294799	0.30	–0.06	0.05	–0.63	7.76	–0.99	32	–0.031	AS
35	EXP 02	–	+	–	–	–	+	7.964156	0.29	–0.04	–3.63	0.59	–0.11	–0.31	32	–0.010	FS
36	EXP 34	+	+	–	–	–	+	8.102536	0.28	–0.01	–2.78	–0.82	–0.09	–0.06	32	–0.002	AFS
37	EXP 26	–	–	+	–	–	+	7.732808	0.12	0.01	–1.16	–0.48	–0.12	–2.15	32	–0.067	CS
38	EXP 58	+	–	+	–	–	+	7.870166	0.10	–0.06	–0.48	–0.37	–0.13	0.19	32	0.006	ACS
39	EXP 10	–	+	+	–	–	+	7.716461	0.25	–0.09	–4.47	–0.04	0.06	0.39	32	0.012	FCS
40	EXP 42	+	+	+	–	–	+	7.938802	0.25	–0.09	–3.38	–0.53	–0.04	0.31	32	0.010	AFCS
41	EXP 22	–	–	–	+	–	+	8.024207	0.46	–0.28	–0.07	0.01	–5.49	–0.16	32	–0.005	IS
42	EXP 54	+	–	–	+	–	+	8.157370	0.44	0.05	0.28	–0.13	–6.21	0.28	32	0.009	AIS
43	EXP 06	–	+	–	+	–	+	8.031060	0.08	0.01	–0.70	0.19	–1.24	0.02	32	0.001	FIS
44	EXP 38	+	+	–	+	–	+	8.162[illegible]1	0.12	–0.05	–0.33	–0.29	–0.93	–0.11	32	–0.003	AFIS
45	EXP 30	–	–	+	+	–	+	7.870548	0.29	–0.02	–0.02	0.03	–0.05	–0.11	32	–0.004	CIS
46	EXP 62	+	–	+	+	–	+	8.098643	0.24	–0.04	0.17	–0.03	–0.24	0.05	32	0.002	ACIS
47	EXP 14	–	+	+	+	–	+	7.858254	0.09	–0.20	–0.68	–0.00	0.08	–0.47	32	–0.015	FCIS
48	EXP 46	+	+	+	+	–	+	8.064007	0.12	–0.14	–0.10	–0.10	0.17	–0.02	32	–0.001	AFCIS
49	EXP 16	–	–	–	–	+	+	8.884887	0.24	–0.04	–0.05	1.03	–1.19	–0.26	32	–0.008	GS
50	EXP 48	+	–	–	–	+	+	9.307013	0.14	–0.01	0.04	0.85	–1.42	0.02	32	0.000	AGS
51	EXP 00	–	+	–	–	+	+	8.893847	0.14	–0.02	–0.07	0.67	0.11	–0.01	32	–0.000	FGS
52	EXP 32	+	+	–	–	+	+	9.280985	0.22	0.00	–0.00	1.09	–0.49	–0.11	32	–0.003	AFGS
53	EXP 24	–	–	+	–	+	+	7.961370	0.13	–0.02	0.33	0.34	–0.14	–0.72	32	–0.023	CGS
54	EXP 56	+	–	+	–	+	+	8.005033	0.13	0.04	–0.06	0.37	–0.48	0.31	32	0.010	ACGS
55	EXP 08	–	+	+	–	+	+	7.921898	0.23	–0.05	–0.02	0.19	–0.07	–0.19	32	–0.006	FCGS
56	EXP 40	+	+	+	–	+	+	8.007367	0.21	0.03	0.05	0.58	–0.10	0.09	32	0.003	AFCGS
57	EXP 20	–	–	–	+	+	+	8.792701	0.42	–0.10	0.04	0.09	–0.18	–0.22	32	–0.007	IGS
58	EXP 52	+	–	–	+	+	+	9.009325	0.39	0.08	0.02	0.06	0.42	–0.60	32	–0.019	AIGS
59	EXP 04	–	+	–	+	+	+	8.784162	0.04	–0.00	0.06	–0.39	0.03	–0.34	32	–0.010	FIGS
60	EXP 36	+	+	–	+	+	+	8.822817	0.09	–0.02	0.08	0.07	0.39	–0.03	32	–0.001	AFIGS
61	EXP 28	–	–	+	+	+	+	8.027150	0.22	–0.03	0.19	–0.02	–0.02	0.60	32	0.019	CIGS
62	EXP 60	+	–	+	+	+	+	8.061171	0.04	0.04	–0.02	0.01	0.46	0.36	32	0.011	ACIGS
63	EXP 12	–	+	+	+	+	+	7.912423	0.03	–0.18	0.08	–0.21	0.03	0.49	32	0.015	FCIGS
64	EXP 44	+	+	+	+	+	+	8.031060	0.12	0.08	0.26	0.19	0.40	0.36	32	0.011	AFCIGS

Table 34A. Yate's algorithm. Results for Productive Flight Hours - Transformed to Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Productive Flight Hours	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identification
1	EXP 19	-	-	-	-	-	-	4.709530	9.50	18.99	42.26	80.42	174.47	350.02	64	5.4691	average
2	EXP 51	+	-	-	-	-	-	4.787492	9.50	23.26	38.16	94.05	175.55	3.69	32	0.1152	A
3	EXP 03	-	+	-	-	-	-	4.691348	11.63	16.03	50.20	80.97	1.98	-0.10	32	-0.0030	F
4	EXP 35	+	+	-	-	-	-	4.804021	11.63	22.13	43.85	94.58	1.70	0.28	32	0.0089	AF
5	EXP 27	-	-	+	-	-	-	5.686975	8.01	24.58	42.61	1.30	-0.12	24.89	32	0.7780	C
6	EXP 59	+	-	+	-	-	-	5.942799	8.01	25.62	38.37	0.68	0.02	0.94	32	0.0294	AC
7	EXP 11	-	+	+	-	-	-	5.669881	11.07	21.32	50.46	1.07	0.19	-0.54	32	-0.0169	FC
8	EXP 43	+	+	+	-	-	-	5.963579	11.07	22.53	44.12	0.63	0.09	0.28	32	0.0088	AFC
9	EXP 23	-	-	-	+	-	-	4.007333	12.34	18.99	0.74	0.00	12.83	-21.03	32	-0.6571	I
10	EXP 55	+	-	-	+	-	-	4.007333	12.24	23.61	0.56	-0.13	12.26	-0.31	32	-0.0097	AI
11	EXP 07	-	+	-	+	-	-	4.007333	12.83	16.08	0.39	0.10	0.49	0.29	32	0.0091	FI
12	EXP 39	+	+	-	+	-	-	4.007333	12.79	22.28	0.29	-0.08	0.45	-0.12	32	-0.0039	AFI
13	EXP 31	-	-	+	+	-	-	5.402677	10.60	24.96	0.46	0.11	-0.17	3.97	32	0.1240	CI
14	EXP 63	+	-	+	+	-	-	5.662960	10.72	25.50	0.61	0.08	-0.33	0.83	32	0.0260	ACI
15	EXP 15	-	+	+	+	-	-	5.384495	11.32	21.60	0.41	-0.07	0.12	-0.55	32	-0.0173	FCI
16	EXP 47	+	+	+	+	-	-	5.683580	11.21	22.51	0.23	0.17	0.17	0.18	32	0.0056	AFCI
17	EXP 17	-	-	-	-	+	-	6.104793	9.45	0.19	0.00	10.38	-10.45	27.24	32	0.8511	G
18	EXP 49	+	-	-	-	+	-	6.236370	9.54	0.55	0.00	2.26	-10.58	-1.06	32	-0.0330	AG
19	EXP 01	-	+	-	-	+	-	6.028279	11.80	0.00	-0.14	10.82	-0.28	-0.31	32	-0.0096	FG
20	EXP 33	+	+	-	-	+	-	6.212606	11.81	0.56	0.01	1.44	-0.03	0.21	32	0.0066	AFG
21	EXP 25	-	-	+	-	+	-	6.403574	8.03	0.32	0.10	0.92	0.15	-17.49	32	-0.5467	CG
22	EXP 57	+	-	+	-	+	-	6.426488	8.05	0.07	0.00	-0.43	0.14	-2.55	32	-0.0796	ACG
23	EXP 09	-	+	+	-	+	-	6.369901	11.15	0.24	-0.15	0.83	-0.12	-0.34	32	-0.0105	FCG
24	EXP 41	+	+	+	-	+	-	6.421622	11.13	0.05	0.08	-0.38	-0.01	0.13	32	0.0040	AFCG
25	EXP 21	-	-	-	+	+	-	5.225747	12.52	0.10	0.07	0.01	2.01	-4.36	32	-0.1361	IG
26	EXP 53	+	-	-	+	+	-	5.370638	12.44	0.36	0.04	-0.17	1.96	-0.24	32	-0.0076	AIG
27	EXP 05	-	+	-	+	+	-	5.313206	12.78	0.02	0.08	-0.11	0.26	0.48	32	0.0149	FIG
28	EXP 37	+	+	-	+	+	-	5.407172	12.71	0.59	-0.00	-0.27	0.57	-0.11	32	-0.0035	AFIG
29	EXP 29	-	-	+	+	+	-	5.659482	10.71	0.36	-0.05	0.04	-0.30	-2.86	32	-0.0894	CIG
30	EXP 61	+	-	+	+	+	-	5.862960	10.89	0.05	-0.02	0.07	-0.25	-0.21	32	-0.0067	ACIG
31	EXP 13	-	+	+	+	+	-	5.579730	11.31	0.14	0.10	0.04	0.16	-0.64	32	-0.0200	FCIG
32	EXP 45	+	+	+	+	+	-	5.631212	11.21	0.08	0.07	0.13	0.02	0.13	32	0.0040	AFCIG

Table 34B. Yate's algorithm, Results for Productive Flight Hours - Transformed to Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Productive Flight Hours	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	-	-	-	-	-	+	4.691348	0.08	-0.00	4.27	-4.09	13.64	1.08	32	0.0337	S
34	EXP 50	+	-	-	-	-	+	4.762174	0.11	0.00	6.10	-6.35	13.60	-0.28	32	-0.0088	AS
35	EXP 02	-	+	-	-	-	+	4.753590	0.26	0.00	1.04	-4.24	-0.62	0.15	32	0.0046	FS
36	EXP 34	+	+	-	-	-	+	4.787492	0.29	0.00	1.22	-6.34	-0.44	-0.10	32	-0.0030	AFS
37	EXP 26	-	-	+	-	-	+	5.808142	0.00	-0.10	4.62	-0.18	-0.13	-0.37	32	-0.0115	CS
38	EXP 58	+	-	+	-	-	+	5.993961	0.00	-0.04	6.20	-0.10	-0.18	-0.05	32	-0.0014	ACS
39	EXP 10	-	+	+	-	-	+	5.820083	0.26	0.12	0.53	0.15	-0.03	-0.21	32	-0.0066	FCS
40	EXP 42	+	+	+	-	-	+	5.991465	0.30	-0.11	0.91	-0.18	0.24	0.05	32	0.0015	AFCS
41	EXP 22	-	-	-	+	-	+	4.007333	0.13	0.09	0.36	0.00	-8.12	-0.13	32	-0.0042	IS
42	EXP 54	+	-	-	+	-	+	4.025352	0.18	0.01	0.56	0.15	-9.37	0.24	32	0.0076	AIS
43	EXP 06	-	+	-	+	-	+	4.025352	0.02	0.02	-0.24	-0.09	-1.34	-0.01	32	-0.0004	FIS
44	EXP 38	+	+	-	+	-	+	4.025352	0.05	-0.01	-0.18	0.23	-1.20	0.11	32	0.0035	AFIS
45	EXP 30	-	-	+	+	-	+	5.424950	0.14	-0.09	0.25	-0.03	-0.18	-0.05	32	-0.0017	CIS
46	EXP 62	+	-	+	+	-	+	5.723585	0.09	-0.07	0.57	-0.08	-0.16	0.31	32	0.0098	ACIS
47	EXP 14	-	+	+	+	-	+	5.420535	0.00	0.18	-0.31	0.03	0.03	0.05	32	0.0015	FCIS
48	EXP 46	+	+	+	+	-	+	5.713733	0.05	-0.10	-0.06	-0.03	0.10	-0.14	32	-0.0043	AFCIS
49	EXP 16	-	-	-	-	+	+	6.177944	0.07	0.03	0.01	1.83	-2.26	-0.03	32	-0.0011	GS
50	EXP 48	+	-	-	-	+	+	6.345636	0.03	0.04	[illegible]	0.18	-2.10	0.17	32	0.0055	AGS
51	EXP 00	-	+	-	-	+	+	6.122493	0.19	0.00	0.06	1.58	0.08	-0.05	32	-0.0014	FGS
52	EXP 32	+	+	-	-	+	+	6.315358	0.17	0.04	-0.24	0.38	-0.33	0.28	32	0.0086	AFGS
53	EXP 24	-	-	+	-	+	+	6.398595	0.02	0.05	-0.08	0.20	0.15	-1.25	32	-0.0392	CGS
54	EXP 56	+	-	+	-	+	+	6.383507	0.00	0.03	-0.03	0.06	0.33	0.14	32	0.0043	ACGS
55	EXP 08	-	+	+	-	+	+	6.326149	0.30	-0.05	0.02	0.32	-0.05	0.03	32	0.0008	FCGS
56	EXP 40	+	+	+	-	+	+	6.386879	0.29	0.05	-0.28	0.25	-0.06	0.06	32	0.0020	AFCGS
57	EXP 20	-	-	-	+	+	+	5.318120	0.17	-0.04	0.00	-0.00	-1.66	0.17	32	0.0052	IGS
58	EXP 52	+	-	-	+	+	+	5.393628	0.19	-0.01	0.04	-0.30	-1.20	-0.41	32	-0.0129	AIGS
59	EXP 04	-	+	-	+	+	+	5.411646	-0.02	-0.02	-0.02	0.05	-0.14	0.18	32	0.0055	FIGS
60	EXP 36	+	+	-	+	+	+	5.480639	0.06	-0.01	0.10	-0.30	-0.07	-0.01	32	-0.0003	AFIGS
61	EXP 28	-	-	+	+	+	+	5.652489	0.08	0.03	0.02	0.04	-0.29	0.45	32	0.0142	CIGS
62	EXP 60	+	-	+	+	+	+	5.655992	0.07	0.08	0.01	0.12	-0.35	0.07	32	0.0023	ACIGS
63	EXP 12	-	+	+	+	+	+	5.564520	0.00	-0.01	0.05	-0.01	0.09	-0.05	32	-0.0016	FCIGS
64	EXP 44	+	+	+	+	+	+	5.641907	0.08	0.07	0.08	0.03	0.04	-0.05	32	-0.0015	AFCIGS

Table 35A. Yate's algorithm, Results for Productive Sorties Flown – Transformed to Natural Logarithms

Test Condition Number	Run Number	A	F	C	I	G	S	Productive Sorties Flown	(1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
		Design Matrix Variables							Algorithm								
1	EXP 19	–	–	–	–	–	–	5.802118	11.67	23.33	49.23	99.68	208.77	418.84	64	6.5443	average
2	EXP 51	+	–	–	–	–	–	5.863631	11.66	25.90	50.45	109.09	210.07	2.71	32	0.0847	A
3	EXP 03	–	+	–	–	–	–	5.789960	12.95	23.11	54.96	100.32	1.49	–0.21	32	–0.0064	F
4	EXP 35	+	+	–	–	–	–	5.874931	12.95	27.34	54.12	109.75	1.22	0.25	32	0.0078	AF
5	EXP 27	–	–	+	–	–	–	6.390241	11.55	26.96	49.69	0.78	–0.16	17.51	32	0.5471	C
6	EXP 59	+	–	+	–	–	–	6.562444	11.56	28.00	50.63	0.71	–0.05	0.17	32	0.0053	AC
7	EXP 11	–	+	+	–	–	–	6.383507	13.67	26.49	55.33	0.59	0.12	–0.68	32	–0.0214	FC
8	EXP 43	+	+	+	–	–	–	6.565265	13.67	27.64	54.42	0.63	0.13	0.18	32	0.0058	AFC
9	EXP 23	–	–	–	+	–	–	5.780744	13.53	23.37	0.50	0.00	8.99	0.40	32	0.0126	I
10	EXP 55	+	–	–	+	–	–	5.771441	13.43	26.32	0.27	–0.16	8.52	–0.36	32	–0.0112	AI
11	EXP 07	–	+	–	+	–	–	5.780744	14.03	23.17	0.38	0.06	0.11	0.29	32	0.0090	FI
12	EXP 39	+	+	–	+	–	–	5.777652	13.97	27.46	0.34	–0.10	0.06	–0.11	32	–0.0035	AFI
13	EXP 31	–	–	+	+	–	–	6.768493	13.17	27.43	0.26	0.06	–0.26	3.44	32	0.1074	CI
14	EXP 63	+	–	+	+	–	–	6.900731	13.31	27.90	0.33	0.05	–0.42	0.48	32	0.0151	ACI
15	EXP 15	–	+	+	+	–	–	6.756932	13.89	26.81	0.39	–0.01	0.06	–0.58	32	–0.0181	FCI
16	EXP 47	+	+	+	+	–	–	6.911747	13.74	27.61	0.24	0.15	0.13	0.12	32	0.0038	AFCI
17	EXP 17	–	–	–	–	+	–	6.704414	11.65	0.15	–0.00	6.80	0.38	18.83	32	0.5886	G
18	EXP 49	+	–	–	–	+	–	6.822197	11.73	0.35	0.01	2.19	0.03	–0.01	32	–0.0005	AG
19	EXP 01	–	+	–	–	+	–	6.630683	13.17	–0.01	–0.15	7.24	–0.27	–0.32	32	–0.0101	FG
20	EXP 33	+	+	–	–	+	–	6.803505	13.15	0.29	–0.01	1.28	–0.09	0.15	32	0.0047	AFG
21	EXP 25	–	–	+	–	+	–	7.000334	11.58	0.29	0.06	0.51	0.16	–10.56	32	–0.3301	CG
22	EXP 57	+	–	+	–	+	–	7.031741	11.59	0.09	–0.01	–0.40	0.13	–1.75	32	–0.0546	ACG
23	EXP 09	–	+	+	–	+	–	6.958448	13.74	0.27	–0.15	0.45	–0.11	–0.44	32	–0.0138	FCG
24	EXP 41	+	+	+	–	+	–	7.013016	13.73	0.07	0.05	–0.39	–0.01	0.07	32	0.0022	AFCG
25	EXP 21	–	–	–	+	+	–	6.507278	13.76	0.06	0.03	–0.01	1.76	–3.91	32	–0.1222	IG
26	EXP 53	+	–	–	+	+	–	6.666957	13.67	0.20	0.03	–0.25	1.67	–0.03	32	–0.0010	AIG
27	EXP 05	–	+	–	+	+	–	6.603944	13.99	0.00	0.08	–0.11	0.10	0.41	32	0.0128	FIG
28	EXP 37	+	+	–	+	+	–	6.709304	13.92	0.32	–0.02	–0.31	0.38	–0.14	32	–0.0044	AFIG
29	EXP 29	–	–	+	+	+	–	6.935370	13.31	0.34	–0.02	0.00	–0.32	–2.57	32	–0.0804	CIG
30	EXP 61	+	–	+	+	+	–	6.955593	13.50	0.05	0.00	0.05	–0.26	–0.07	32	–0.0023	ACIG
31	EXP 13	–	+	+	+	+	–	6.846943	13.87	0.17	0.09	0.05	0.15	–0.74	32	–0.0233	FCIG
32	EXP 45	+	+	+	+	+	–	6.897705	13.74	0.07	0.06	0.07	–0.03	0.13	32	0.0041	AFCIG

Table 35B. Yate's algorithm, Results for Productive Sorties Flown - Transformed to Natural Logarithms

Test Condition Number	Run Number	Design Matrix Variables A	F	C	I	G	S	Productive Sorties Flown	Algorithm (1)	(2)	(3)	(4)	(5)	(6)	Divisor	Estimate	Identi-fication
33	EXP 18	−	−	−	−	−	+	5.799093	0.06	-0.00	2.57	1.22	9.41	1.30	32	0.0407	S
34	EXP 50	+	−	−	−	−	+	5.946439	0.08	-0.00	4.23	-0.84	9.43	-0.27	32	-0.0083	AS
35	EXP 02	−	+	−	−	−	+	5.855072	0.17	0.01	1.04	0.94	-0.06	0.11	32	0.0035	FS
36	EXP 34	+	+	−	−	−	+	5.872118	0.18	-0.00	1.15	-0.91	0.05	0.02	32	0.0005	AFS
37	EXP 26	−	−	+	−	−	+	6.538140	-0.01	-0.09	2.94	-0.23	-0.16	-0.47	32	-0.0147	CS
38	EXP 58	+	−	+	−	−	+	6.629363	-0.00	-0.06	4.29	-0.04	-0.16	-0.05	32	-0.0014	ACS
39	EXP 10	−	+	+	−	−	+	6.522093	0.13	0.14	0.48	0.06	-0.01	-0.16	32	-0.0049	FCS
40	EXP 42	+	+	+	−	−	+	6.628041	0.15	-0.15	0.80	-0.15	0.16	0.07	32	0.0023	AFCS
41	EXP 22	−	−	−	+	−	+	5.789960	0.12	0.08	0.21	0.01	-4.81	-0.35	32	-0.0109	IS
42	EXP 54	+	−	−	+	−	+	5.793014	0.17	-0.02	0.30	0.15	-5.98	0.18	32	0.0055	AIS
43	EXP 06	−	+	−	+	−	+	5.793014	0.03	0.00	-0.20	-0.07	-0.91	-0.02	32	-0.0007	FIS
44	EXP 38	+	+	−	+	−	+	5.793014	0.05	-0.01	-0.19	0.20	-0.84	0.10	32	0.0031	AFIS
45	EXP 30	−	−	+	+	−	+	6.788972	0.16	-0.09	0.13	-0.00	-0.24	-0.09	32	-0.0027	CIS
46	EXP 62	+	−	+	+	−	+	6.946976	0.11	-0.07	0.32	-0.10	-0.20	0.28	32	0.0087	ACIS
47	EXP 14	−	+	+	+	−	+	6.781058	0.02	0.19	-0.29	0.02	0.05	0.06	32	0.0019	FCIS
48	EXP 46	+	+	+	+	−	+	6.945051	0.05	-0.14	-0.10	-0.02	0.02	-0.17	32	-0.0054	AFCIS
49	EXP 16	−	−	−	−	+	+	6.799056	0.05	0.02	-0.00	1.66	-2.06	0.02	32	0.0006	GS
50	EXP 48	+	−	−	−	+	+	6.957497	0.02	0.01	-0.01	0.11	-1.85	0.11	32	0.0035	AGS
51	EXP 00	−	+	−	−	+	+	6.742881	0.09	0.01	0.03	1.35	0.19	-0.00	32	-0.0000	FGS
52	EXP 32	+	+	−	−	+	+	6.927558	0.11	0.02	-0.29	0.33	-0.22	0.17	32	0.0052	AFGS
53	EXP 24	−	−	+	−	+	+	6.994850	0.00	0.06	-0.10	0.09	0.14	-1.35	32	-0.0422	CGS
54	EXP 56	+	−	+	−	+	+	6.991177	0.00	0.02	-0.01	0.01	0.28	0.06	32	0.0020	ACGS
55	EXP 08	−	+	+	−	+	+	6.931472	0.16	-0.05	0.02	0.19	-0.10	0.05	32	0.0015	FCGS
56	EXP 40	+	+	+	−	+	+	6.986586	0.16	0.03	-0.33	0.19	-0.04	-0.03	32	-0.0009	AFCGS
57	EXP 20	−	−	−	+	+	+	6.614726	0.16	-0.03	-0.01	-0.00	-1.55	0.20	32	0.0064	IGS
58	EXP 52	+	−	−	+	+	+	6.694562	0.18	0.01	0.02	-0.32	-1.02	-0.40	32	-0.0126	AIGS
59	EXP 04	−	+	−	+	+	+	6.704414	-0.00	-0.00	-0.03	0.09	-0.08	0.14	32	0.0044	FIGS
60	EXP 36	+	+	−	+	+	+	6.793466	0.06	0.01	0.08	-0.35	0.01	0.06	32	0.0017	AFIGS
61	EXP 28	−	−	+	+	+	+	6.932448	0.08	0.03	0.05	0.03	-0.31	0.53	32	0.0165	CIGS
62	EXP 60	+	−	+	+	+	+	6.942157	0.09	0.06	0.01	0.12	-0.43	0.09	32	0.0028	ACIGS
63	EXP 12	−	+	+	+	+	+	6.837333	0.01	0.01	0.03	-0.04	0.09	-0.12	32	-0.0037	FCIGS
64	EXP 44	+	+	+	+	+	+	6.898715	0.06	0.05	0.04	0.01	0.05	-0.04	32	-0.0013	AFCIGS

Appendix J: Difference Between Two Averages - Calculations for Estimate of Effect and Standard Error for Transformed Results

Table 36. Summary of Estimated Effects of Conditions on the Ratio of Cargo Delivered – Results Transformed to Natural Logarithms

	RATIO ON TIME	RATIO DELIVERED
Average:		
	−1.535428	−0.664018
Two Factor Interaction Effects:		
AF	0.008980	0.007268
AC	0.045037	0.001407
AI	−0.009631	−0.000609
AG	0.009410	0.007187
AS	−0.009184	−0.002047
FC	0.001497	−0.015130
FI	0.000950	0.005321
FG	0.019679	0.027778
FS	0.005985	0.003353
CI	0.006768	−0.008462
CG	0.090673	−0.088493
CS	0.015203	−0.010836
IG	0.000525	0.013172
IS	−0.006498	−0.010601
GS	0.027544	0.020854
Three Factor Interaction Effects:		
AFC	0.002996	0.005060
AFI	−0.000638	−0.000456
AFG	0.008980	0.004841
AFS	−0.001467	0.000903
ACI	0.008267	0.000229
ACG	−0.014899	−0.024146
ACS	−0.008159	−0.001521
AIG	−0.010174	−0.000940
AIS	−0.001753	−0.001168
AGS	0.004182	0.000711
FCI	0.000522	−0.007413
FCG	0.001497	−0.012702
FCS	0.000314	−0.000413
FIG	0.000950	0.005321
FIS	−0.000830	0.001407
FGS	0.005985	0.000926
CIG	0.018423	0.009734
CIS	−0.001111	−0.002410
CGS	−0.009276	−0.031459
IGS	0.005157	0.003007

	RATIO ON TIME	RATIO DELIVERED
Main Effects:		
A	0.069347	0.032740
F	0.019679	0.025351
C	0.647986	0.643881
I	−0.011130	−0.005024
G	0.612359	0.633737
S	0.052023	0.041477
Four Factor Interaction Effects:		
AFCI	−0.001066	0.001112
AFCG	0.002996	0.002633
AFCS	0.005059	−0.000070
AFIG	−0.000638	−0.000456
AFIS	0.000829	0.000417
AFGS	−0.001467	0.003331
ACIG	0.007724	−0.000102
ACIS	0.003635	0.006757
ACGS	0.005206	0.001238
AIGS	−0.002295	−0.006087
FCIG	0.000522	−0.007413
FCIS	−0.000945	0.000615
FCGS	0.000314	−0.002840
FIGS	−0.000830	0.001407
CIGS	0.010545	0.011198
Five Factor Interaction Effects:		
AFCIG	−0.001066	0.001112
AFCIS	0.000714	−0.001142
AFCGS	0.005059	0.002357
AFIGS	0.000829	0.000417
ACIGS	0.003093	0.001839
FCIGS	−0.000945	0.000615
Six Factor Interaction Effect:		
AFCGIS	0.000714	−0.001142

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

	RATIO ON TIME	RATIO DELIVERED
Sum of squares:	0.001363	0.002293
Variance:	0.000032	0.000055
Est of Std Dev:	0.005696	0.007389

Table 37. Summary of Estimated Effects of Conditions on the Number of Hours Flown – Results Transformed to Natural Logarithms

	FLIGHT HOURS	FLIGHT HOURS
Average:	7.163	5.469
Main Effects:		
A	0.214	0.115
F	−0.022	−0.003
C	−0.501	0.778
I	−0.671	−0.657
G	0.607	0.851
S	0.087	0.034
Two Factor Interaction Effects:		
AF	−0.006	0.009
AC	−0.022	0.029
AI	−0.045	−0.010
AG	−0.025	−0.033
AS	−0.031	−0.009
FC	0.005	−0.017
FI	−0.008	0.009
FG	−0.006	−0.010
FS	−0.006	0.005
CI	0.112	0.124
CG	−0.462	−0.547
CS	−0.062	−0.012
IG	−0.106	−0.136
IS	−0.003	−0.004
GS	−0.004	−0.001
Three Factor Interaction Effects:		
AFC	0.025	0.009
AFI	−0.002	−0.004
AFG	0.003	0.007
AFS	−0.003	−0.003
ACI	0.054	0.026
ACG	−0.061	−0.080
ACS	0.007	−0.001
AIG	−0.013	−0.008
AIS	0.007	0.008
AGS	0.002	0.005
FCI	−0.004	−0.017
FCG	−0.007	−0.011
FCS	0.010	−0.007
FIG	−0.016	0.015
FIS	−0.001	−0.000
FGS	−0.001	−0.001
CIG	−0.035	−0.089
CIS	0.000	−0.002
CGS	−0.027	−0.039
IGS	−0.012	0.005
Four Factor Interaction Effects:		
AFCI	−0.001	0.006
AFCG	0.009	0.004
AFCS	0.010	0.002
AFIG	−0.006	−0.004
AFIS	−0.003	0.004
AFGS	−0.002	0.009
ACIG	0.008	−0.007
ACIS	0.003	0.010
ACGS	0.012	0.004
AIGS	−0.015	−0.013
FCIG	0.012	−0.020
FCIS	−0.012	0.001
FCGS	−0.003	0.001
FIGS	−0.008	0.005
CIGS	0.020	0.014
Five Factor Interaction Effects:		
AFCIG	0.013	0.004
AFCIS	−0.003	−0.004
AFCGS	0.003	0.002
AFIGS	−0.003	−0.000
ACIGS	0.010	0.002
FCIGS	0.013	−0.002
Six Factor Interaction Effect:		
AFCGIS	0.011	−0.001

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

Sum of squares:	0.012109	0.018697
Variance:	0.000288	0.000445
Est of Std Dev:	0.016979	0.021099

Table 38. Summary of Estimated Effects of Conditions on the Number of Sorties Flown – Results Transformed to Natural Logarithms

	TOTAL SORTIES	PRODUCTIVE SORTIES
Average:		
	8.197	6.544
Two Factor Interaction Effects:		
AF	−0.006	0.008
AC	−0.046	0.005
AI	−0.044	−0.011
AG	−0.006	−0.000
AS	−0.031	−0.008
FC	0.007	−0.021
FI	−0.007	0.009
FG	−0.008	−0.010
FS	−0.010	0.004
CI	0.114	0.107
CG	−0.365	−0.330
CS	−0.067	−0.015
IG	−0.082	−0.122
IS	−0.005	−0.011
GS	−0.008	0.001
Three Factor Interaction Effects:		
AFC	0.022	0.006
AFI	−0.003	−0.003
AFG	0.001	0.005
AFS	−0.002	0.001
ACI	0.046	0.015
ACG	−0.068	−0.055
ACS	0.006	−0.001
AIG	−0.012	−0.001
AIS	0.009	0.005
AGS	0.000	0.003
FCI	−0.005	−0.018
FCG	−0.009	−0.014
FCS	0.012	−0.005
FIG	−0.019	0.013
FIS	0.001	−0.001
FGS	−0.000	−0.000
CIG	0.008	−0.080
CIS	−0.004	−0.003
CGS	−0.023	−0.042
IGS	−0.007	0.006

	TOTAL SORTIES	PRODUCTIVE SORTIES
Main Effects:		
A	0.205	0.085
F	−0.031	−0.006
C	−0.526	0.547
I	−0.009	0.013
G	0.493	0.589
S	0.084	0.041
Four Factor Interaction Effects:		
AFCI	−0.001	0.004
AFCG	0.008	0.002
AFCS	0.010	0.002
AFIG	−0.005	−0.004
AFIS	−0.003	0.003
AFGS	−0.003	0.005
ACIG	0.013	−0.002
ACIS	0.002	0.009
ACGS	0.010	0.002
AIGS	−0.019	−0.013
FCIG	0.014	−0.023
FCIS	−0.015	0.002
FCGS	−0.006	0.001
FIGS	−0.010	0.004
CIGS	0.019	0.017
Five Factor Interaction Effects		
AFCIG	0.013	0.004
AFCIS	−0.001	−0.005
AFCGS	0.003	−0.001
AFIGS	−0.001	0.002
ACIGS	0.011	0.003
FCIGS	0.015	−0.004
Six Factor Interaction Effect:		
AFCGIS	0.011	−0.001

Calculation of Standard Error for Effects using 3, 4, 5 and 6 factor interactions:

	TOTAL SORTIES	PRODUCTIVE SORTIES
Sum of squares:	0.011187	0.013558
Variance:	0.000266	0.000323
Est of Std Dev:	0.016321	0.017967

Appendix K: Experimental Results Transformed to Natural Logarithms

Table 39A. Experimental Results Transformed to Natural Logarithms:
GAMM Central American Scenario

Test Condition Number	Run No	Ratio On Time	Ratio Delivered	Total Flight Hours	Total Sorties	Productive Flight Hours	Productive Sorties
1	EXP 19	-2.120264	-1.347074	7.008505	7.821643	4.709530	5.802118
2	EXP 51	-2.120264	-1.347074	7.364547	8.163086	4.787492	5.863631
3	EXP 03	-2.120264	-1.347074	7.027315	7.841493	4.691348	5.789960
4	EXP 35	-2.120264	-1.347074	7.344719	8.138273	4.804021	5.874931
5	EXP 27	-1.660731	-0.653926	6.866933	7.616776	5.686975	6.390241
6	EXP 59	-1.514128	-0.597837	7.188413	7.905442	5.942799	6.562444
7	EXP 11	-1.660731	-0.673345	6.844815	7.590852	5.669881	6.383507
8	EXP 43	-1.514128	-0.597837	7.161622	7.873598	5.963579	6.565265
9	EXP 23	-2.120264	-1.347074	6.386879	7.882315	4.007333	5.780744
10	EXP 55	-2.120264	-1.347074	6.520621	8.004366	4.007333	5.771441
11	EXP 07	-2.120264	-1.347074	6.381816	7.870166	4.007333	5.780744
12	EXP 39	-2.120264	-1.347074	6.490724	7.974533	4.007333	5.777652
13	EXP 31	-1.660731	-0.653926	6.455199	7.822044	5.402677	6.768493
14	EXP 63	-1.514128	-0.616186	6.763885	8.072779	5.662960	6.900731
15	EXP 15	-1.660731	-0.673345	6.448889	7.817625	5.384495	6.756932
16	EXP 47	-1.514128	-0.616186	6.765039	8.070281	5.683580	6.911747
17	EXP 17	-1.660731	-0.733969	8.048149	8.665613	6.104793	6.704414
18	EXP 49	-1.609438	-0.693147	8.482809	9.128154	6.236370	6.822197
19	EXP 01	-1.660731	-0.693147	8.074026	8.681351	6.028279	6.630683
20	EXP 33	-1.560648	-0.634878	8.478036	9.120416	6.212606	6.803505
21	EXP 25	-0.967584	-0.105361	7.302496	7.965893	6.403574	7.000334
22	EXP 57	-0.867501	-0.094311	7.400621	8.045588	6.426488	7.031741
23	EXP 09	-0.967584	-0.083382	7.261225	7.916443	6.369901	6.958448
24	EXP 41	-0.820981	-0.051293	7.399398	8.035279	6.421622	7.013016
25	EXP 21	-1.660731	-0.755023	7.346655	8.592301	5.225747	6.507278
26	EXP 53	-1.660731	-0.673345	7.591862	8.880307	5.370638	6.666957
27	EXP 05	-1.660731	-0.653926	7.335634	8.570734	5.313206	6.603944
28	EXP 37	-1.609438	-0.579818	7.532088	8.812397	5.407172	6.709304
29	EXP 29	-0.967584	-0.083382	6.609349	7.998671	5.659482	6.935370
30	EXP 61	-0.867501	-0.083382	6.700731	8.084562	5.662960	6.955593
31	EXP 13	-0.941609	-0.083382	6.545350	7.937732	5.579730	6.846943
32	EXP 45	-0.820981	-0.051293	6.687109	8.052933	5.631212	6.897705

Table 39B Experimental Results Transformed to Natural Logarithms: GAMM Central American Scenario

Test Condition Number	Run No	Ratio On Time	Ratio Delivered	Total Flight Hours	Total Sorties	Productive Flight Hours	Productive Sorties
33	EXP 18	-2.120264	-1.347074	7.191429	8.052615	4.691346	5.799093
34	EXP 50	-2.120264	-1.347074	7.478170	8.294799	4.762174	5.846439
35	EXP 02	-2.120264	-1.347074	7.156177	7.964156	4.753590	5.855072
36	EXP 34	2.120264	-1.347074	7.310550	8.102586	4.787492	5.872118
37	EXP 26	-1.560648	-0.579818	6.981006	7.732808	5.808142	6.538140
38	EXP 58	-1.469676	-0.544727	7.153052	7.870166	5.993961	6.629363
39	EXP 10	-1.560648	-0.579818	6.972606	7.716461	5.820083	6.522093
40	EXP 42	-1.469676	-0.544727	7.222566	7.938802	5.991465	6.628041
41	EXP 22	-2.120264	-1.347074	6.533789	8.024207	4.007333	5.789960
42	EXP 54	-2.120264	-1.347074	6.658011	8.157370	4.025352	5.793014
43	EXP 06	-2.120264	-1.347074	6.543912	8.031060	4.025352	5.793014
44	EXP 38	-2.120264	-1.347074	6.665684	8.162801	4.025352	5.793014
45	EXP 30	-1.609438	-0.653926	6.525030	7.870548	5.424950	6.788972
46	EXP 62	-1.514128	-0.597837	6.805723	8.098643	5.723585	6.946976
47	EXP 14	-1.609438	-0.653926	6.513230	7.858254	5.420535	6.781058
48	EXP 46	-1.514128	-0.597837	6.771936	8.064007	5.713733	6.945051
49	EXP 16	-1.609438	-0.634878	8.283494	8.884887	6.177944	6.799056
50	EXP 48	-1.514128	-0.582119	8.669743	9.307013	6.345636	6.957497
51	EXP 00	-1.560648	-0.579818	8.308225	8.893847	6.122493	6.742881
52	EXP 32	-1.469676	-0.494296	8.651549	9.280985	6.315358	6.927558
53	EXP 24	-0.891598	-0.072571	7.305188	7.961370	6.398595	6.994850
54	EXP 56	-0.820981	-0.083382	7.358194	8.005033	6.383507	6.991177
55	EXP 08	-0.867501	-0.072571	7.265430	7.921898	6.326149	6.931472
56	EXP 40	-0.733969	-0.030459	7.387090	8.007367	6.386879	6.986566
57	EXP 20	-1.609438	-0.653926	7.544332	8.792701	5.318120	6.614726
58	EXP 52	-1.609438	-0.616186	7.716461	9.009325	5.393628	6.694562
59	EXP 04	-1.560648	-0.544727	7.550661	8.784162	5.411646	6.704414
60	EXP 36	-1.560648	-0.494296	7.544332	8.822617	5.480639	6.793466
61	EXP 28	-0.867501	-0.061875	6.630683	8.027150	5.652489	6.932448
62	EXP 60	-0.798508	-0.072571	6.890842	8.061171	5.655992	6.942157
63	EXP 12	-0.843970	-0.061875	6.532334	7.912423	5.564520	6.837333
64	EXP 44	-0.713350	-0.020203	6.683361	8.031060	5.641907	6.898715

Appendix L: Analysis of Initial Regression Equations

Explanation of Analysis

For each regression equation, 64 estimates were calculated with each variable being substituted by either +1 or -1, according to the value of that variable in the design matrix. Then, using all 64 results, the sum of the squares about the mean, the sum of the squares due to the regression, and the sum of the squares of the residuals were calculated.

In the ANOVA table, for each individual measure of effectiveness, the Total Sum of Squares, which is also the sum of the squares about the mean, has the same value. The exception to this is Ratio On Time, where there is one Total Sum of Squares value for the untransformed results, and one for the transformed results.

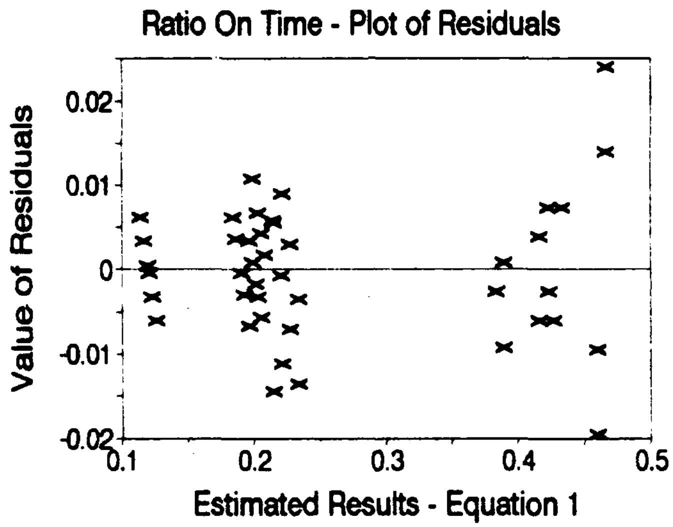
The calculations for each ANOVA table were carried out on a spreadsheet, and, as a result of round off error, the sum of the values for the Sum of Squares of the Regression and the Sum of Squares of the Error do not exactly equal the Total Sum of Squares. The values are accurate to the fourth significant figure, or better.

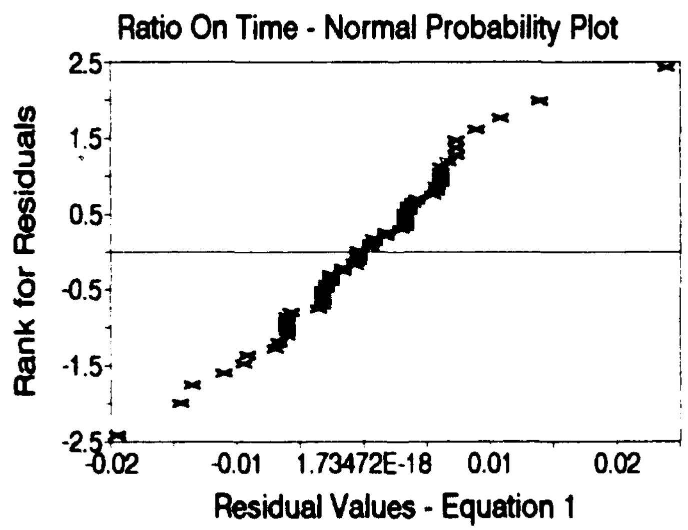
Ratio On Time Function – Equation 1

$$\hat{y}=0.239219+(0.020313/2)A+(0.006562/2)F+(0.155938/2)C +(0.148437/2)G+(0.015312/2)S+(0.065938/2)CG+(0.015313/2)AC +(0.007812/2)AG+(0.007812/2)CS+(0.010312/2)GS$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	10	0.82962	0.08296	1443.848
Error	53	0.00305	0.00006	
Total	63	0.83266		
R^2 0.996343		Adjusted R^2		0.995653



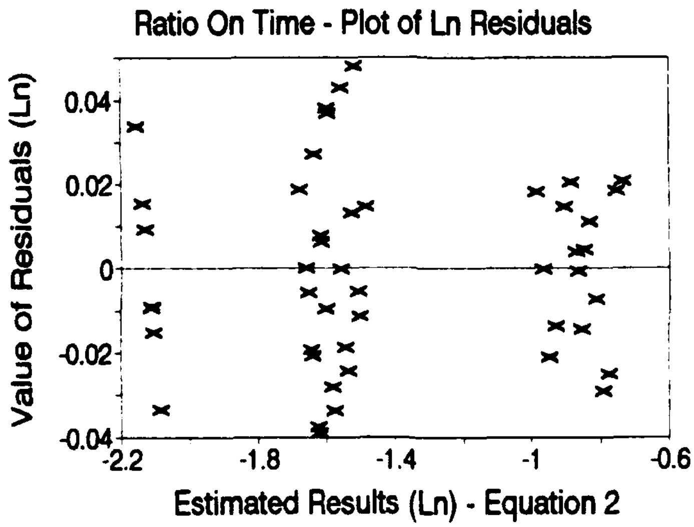


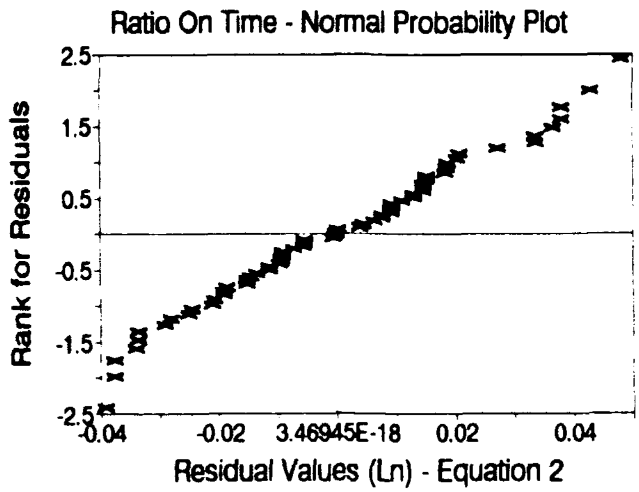
Ratio On Time Function – Equation 2

$$Ln(\hat{y})=-1.535428+(0.069347/2)A+(0.019679/2)F+(0.647986/2)C$$
$$+(0.612359/2)G+(0.052023/2)S+(0.090673/2)CG+(0.045037/2)AC$$
$$-(0.019679/2)FG+(0.027544/2)GS+(0.018423)CIG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	10	13.03193	1.30319	2331.128
Error	53	0.02963	0.00056	
Total	63	13.06174		
R^2 0.997732		Adjusted R^2		0.997304



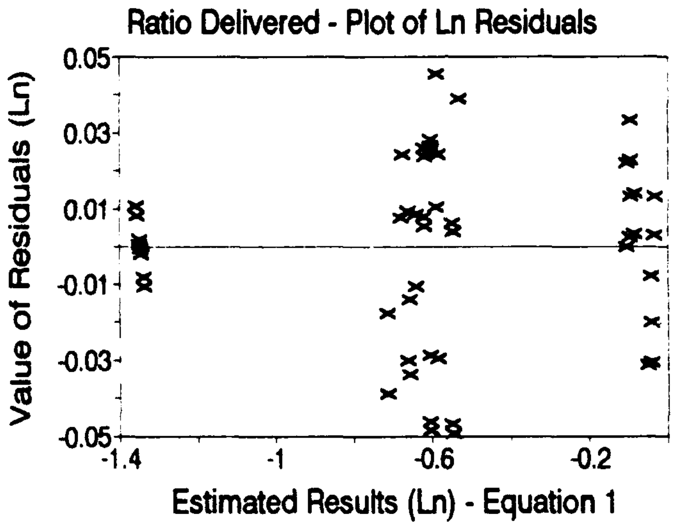


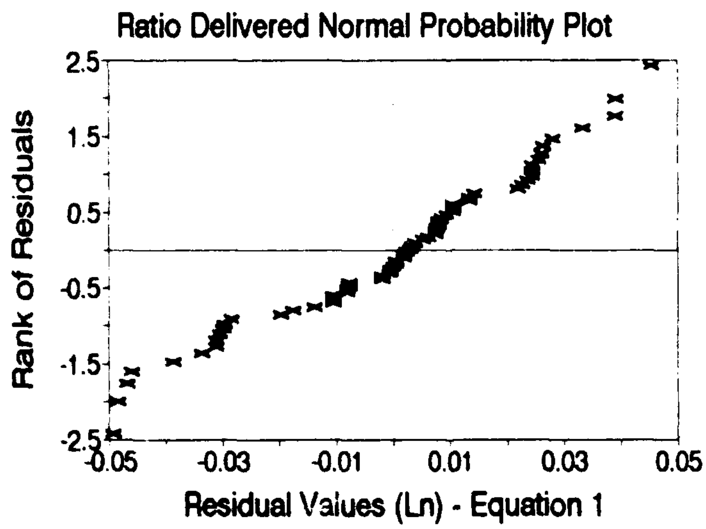
Ratio Delivered Function - Equation 1

$$\mathrm{Ln}(\hat{y}) = -0.664018 + (0.03274/2)A + (0.025351/2)F + (0.643881/2)C + (0.633737/2)G + (0.041477/2)S + (0.027778/2)FG + (-0.088493/2)CG + (-0.024146/2)ACG + (-0.031459/2)CGS$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	9	13.27705	1.47523	2446.741
Error	54	0.03256	0.00060	
Total	63	13.30961		
R^2 0.997554		Adjusted R^2		0.997146



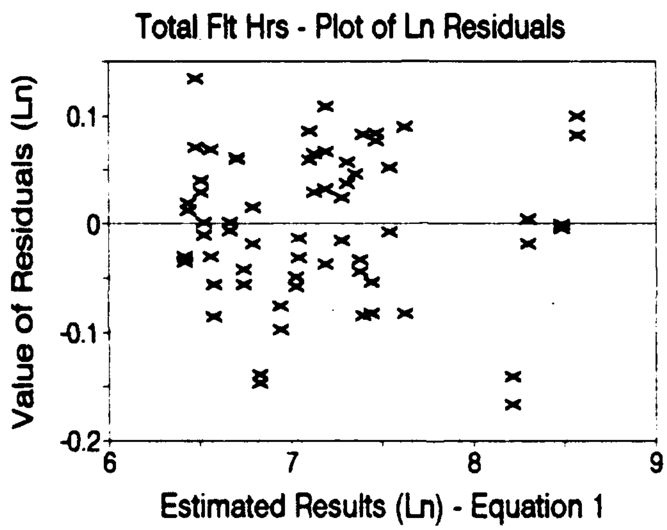


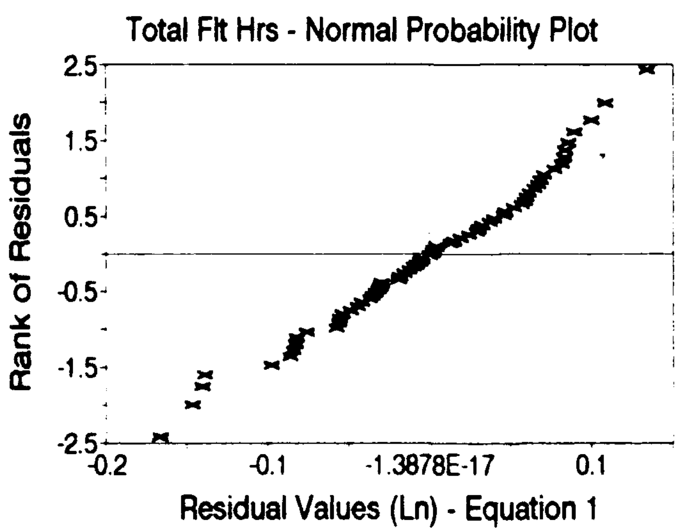
Total Flying Hours Function - Equation 1

$$Ln(\hat{y})=7.163+(0.214/2)A+(-0.501/2)C+(-0.671/2)I+(0.607/2)G$$
$$+(0.087/2)S+(0.122/2)CI+(-0.462/2)CG$$
$$-(-0.106/2)IG+(0.054/2)ACI$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	9	21.81114	2.42346	456.495
Error	54	0.28668	0.00531	
Total	63	22.08462		
R^2 0.987019		Adjusted R^2		0.984856



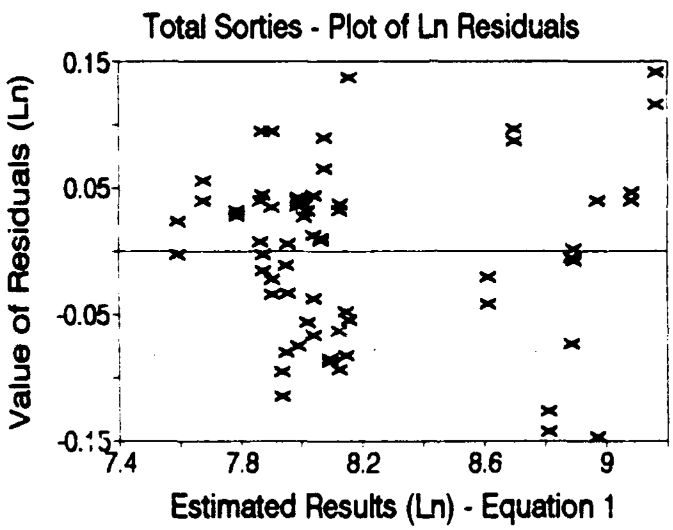


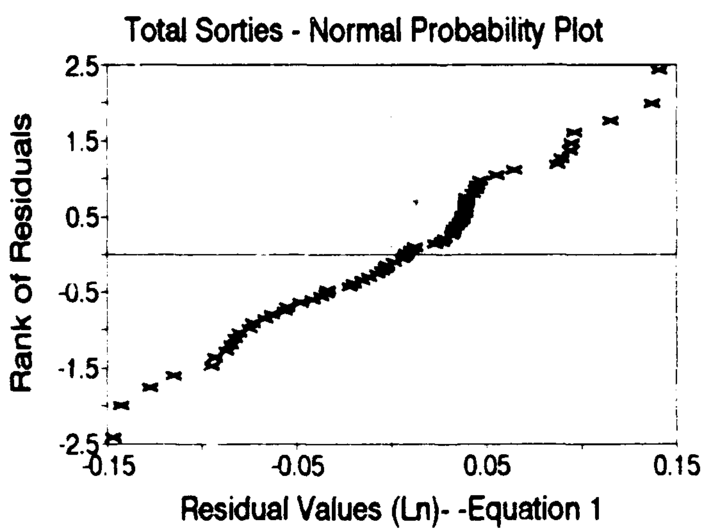
Total Sorties Flown Function – Equation 1

$$Ln(\hat{y})=8.197+(.205/2)A+(-.526/2)C+(.493/2)G+(.084/2)S$$
$$+(.114/2)CI+(-.082/2)IG+(-.365/2)CG+(-.068/2)ACG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	8	11.62200	1.45275	284.49136
Error	55	0.28086	0.00511	
Total	63	11.90955		
R^2 0.976418		Adjusted R^2		0.9729874



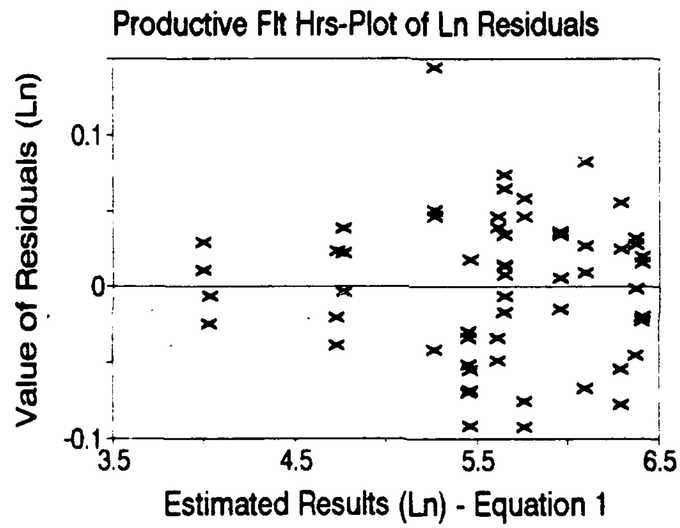


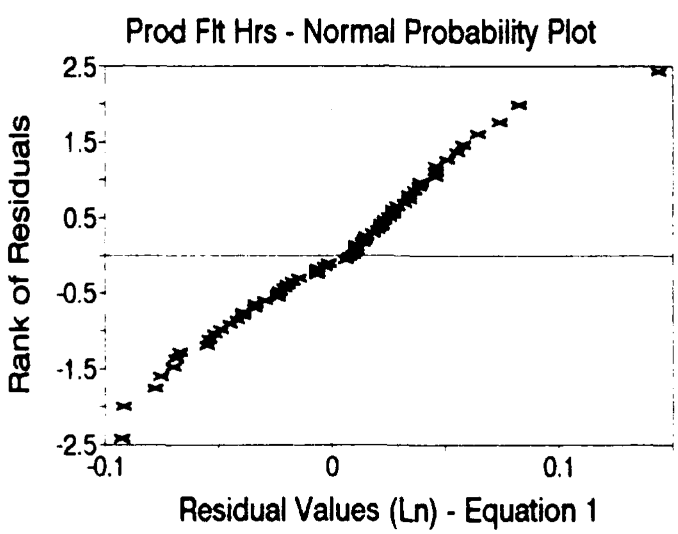
Productive Flying Hours Function - Equation 1

$$Ln(\hat{y})=5.469+(0.115/2)A+(0.778/2)C+(-0.657/2)I+(0.851/2)G$$
$$+(0.124/2)CI+(-0.547/2)CG+(-0.136/2)IG$$
$$+(-0.080/2)ACG+(-0.089/2)CIG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	9	33.94818	3.77202	1524.693
Error	54	0.13359	0.00247	
Total	63	34.08075		
R^2 0.996080		Adjusted R^2		0.995427



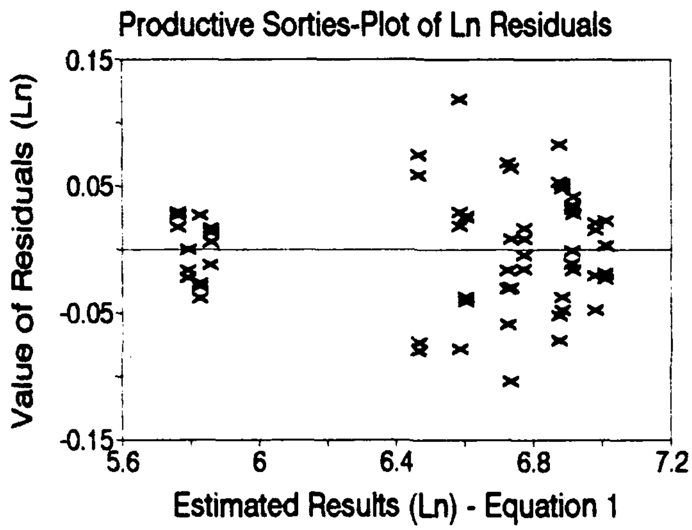


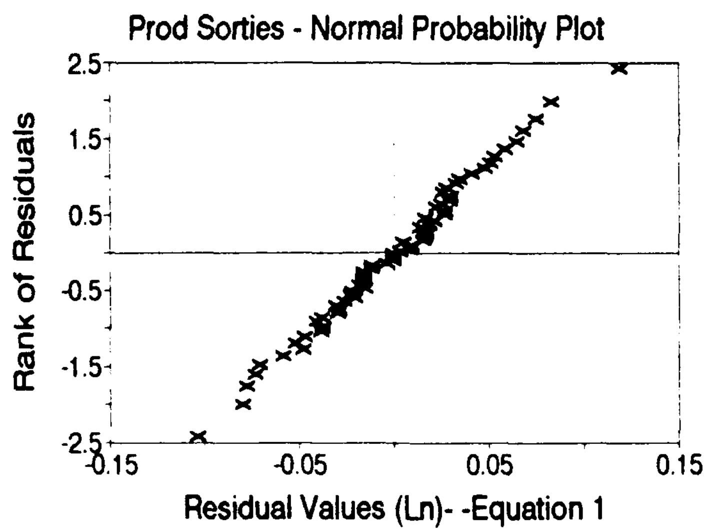
Productive Sorties Function - Equation 1

$$Ln(\hat{y})=6.544+(0.085/2)A+(0.547/2)C+(0.589/2)G+(0.107/2)CG$$
$$+(-0.122/2)IG+(-0.33/2)CG+(-0.055/2)ACG+(-0.08/2)CIG$$

ANOVA TABLE

Source of Variation	Df	Sum of Squares	Mean Square	F
Regression	8	12.76821	1.59603	757.536
Error	55	0.11588	0.00211	
Total	63	12.88112		
R^2 0.99100		Adjusted R^2		0.98970





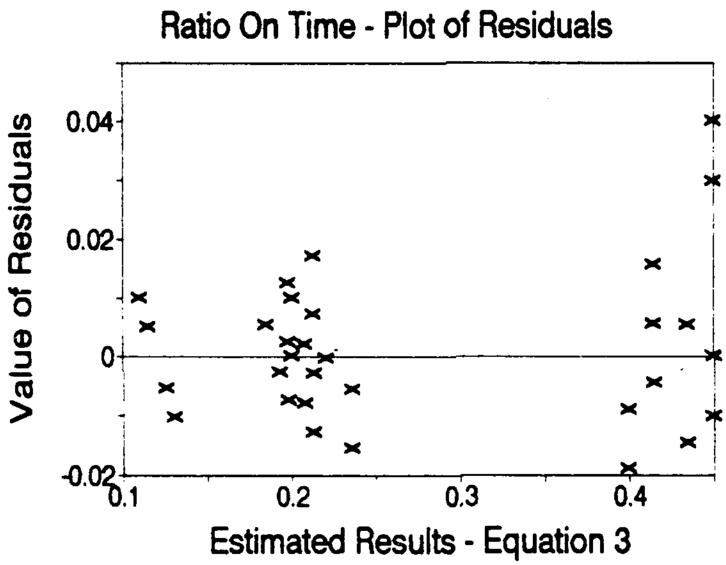
Appendix M: Analysis of Reduced Regression Equations

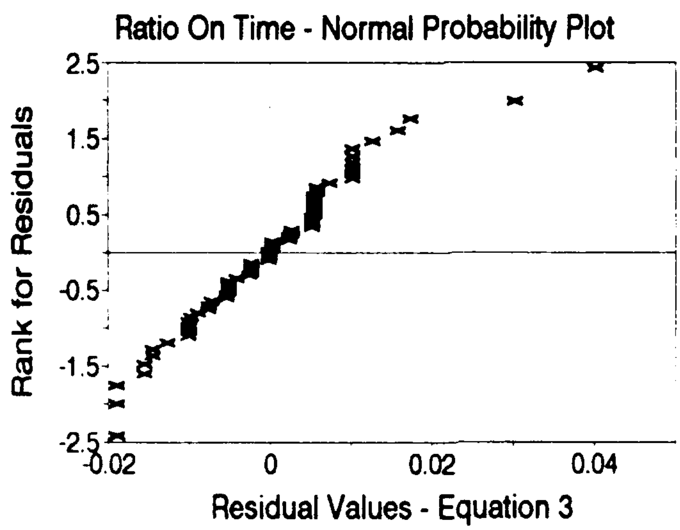
Ratio On Time Function - Equation 3

$$\hat{y}=0.239219+(0.020313/2)A+(0.155938/2)C+(0.148437/2)G$$
$$+(0.015312/2)S+(0.065938/2)CG+(0.015313/2)AC$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	6	0.82527	0.13755	1061.041
Error	57	0.00739	0.00013	
Total	63	0.83266		
R^2 0.991126		Adjusted R^2		0.990192



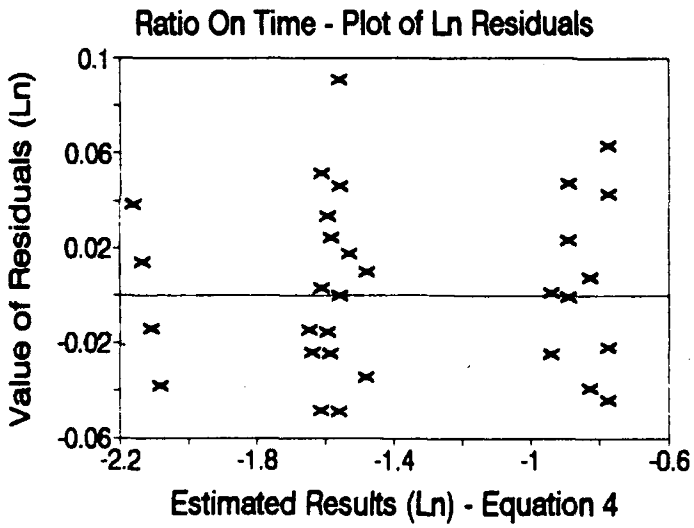


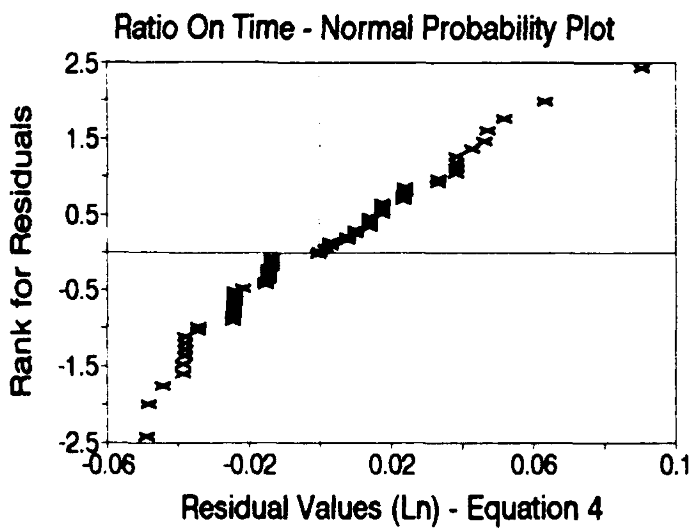
Ratio On Time Function – Equation 4

$$\ln(\hat{y}) = -1.535428 + (0.069347/2)A + (0.647986/2)C + (0.612359/2)G + (0.052023/2)S + (0.090673/2)CG + (0.045037/2)AC$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	6	13.00197	2.16699	2072.789
Error	57	0.05959	0.00105	
Total	63	13.06174		
R^2 0.995438		Adjusted R^2		0.994958



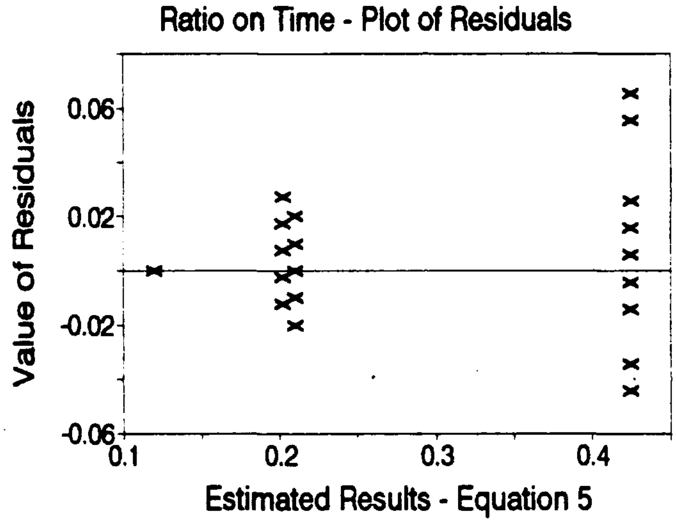


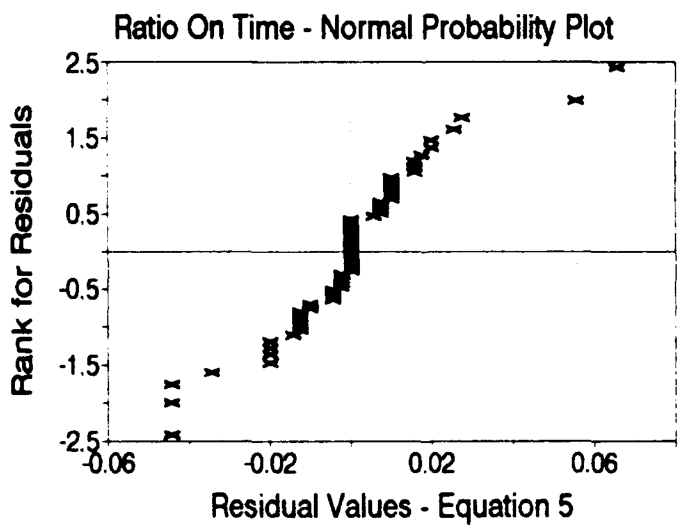
Ratio On Time Function - Equation 5

$\hat{y}=0.239219+(0.155938/2)C+(0.148437/2)G+(0.065938/2)CG$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	3	0.81117	0.27039	754.795
Error	60	0.02149	0.00036	
Total	63	0.83266		
R^2 0.974187		Adjusted R^2		0.972896



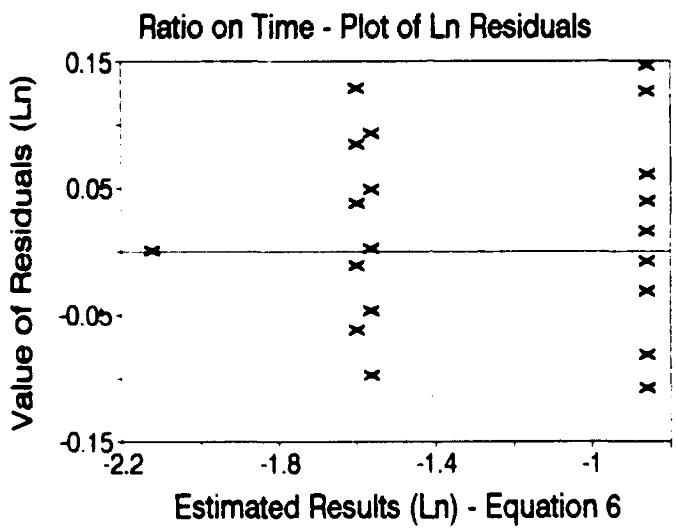


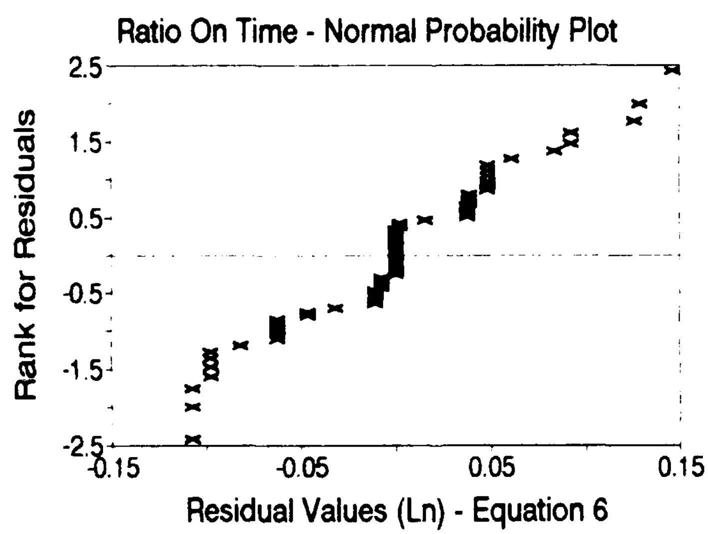
Ratio On Time Function - Equation 6

$$\mathrm{Ln}(\hat{y})=-1.535428+(0.647986/2)C+(0.612359/2)G+(0.090673/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	3	12.84927	4.28309	1210.546
Error	60	0.21229	0.00354	
Total	63	13.06174		
R^2 0.983747		Adjusted R^2		0.982935



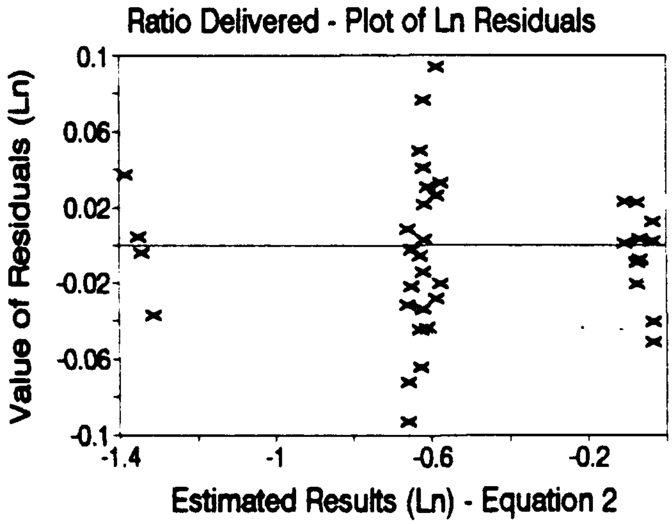


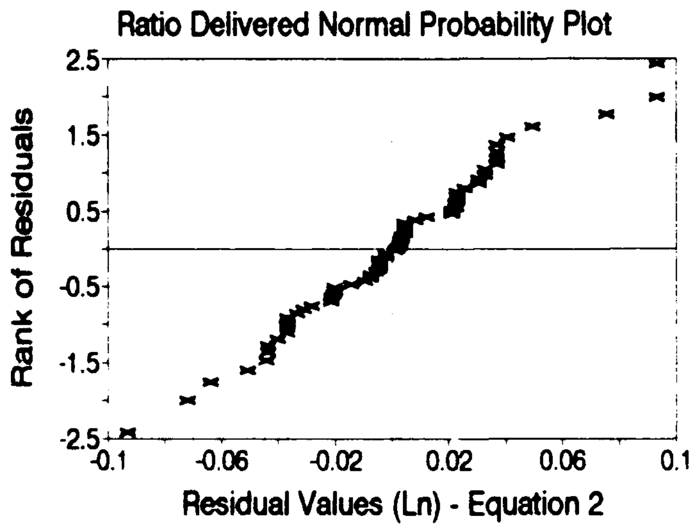
Ratio Delivered Function - Equation 2

$$Ln(\hat{y}) = -0.664018 + (0.03274/2)A + (0.643881/2)C + (0.633737/2)G + (0.041477/2)S + (0.088493/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	5	13.22926	2.64585	1909.870
Error	58	0.08035	0.00139	
Total	63	13.30961		
R^2 0.993963		Adjusted R^2		0.993443



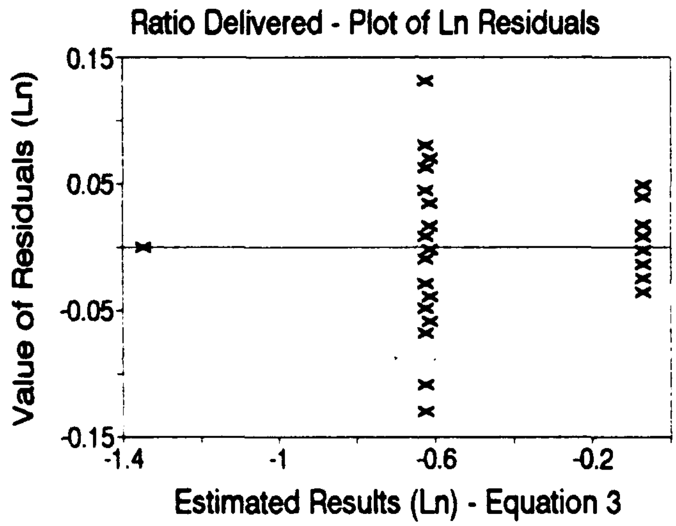


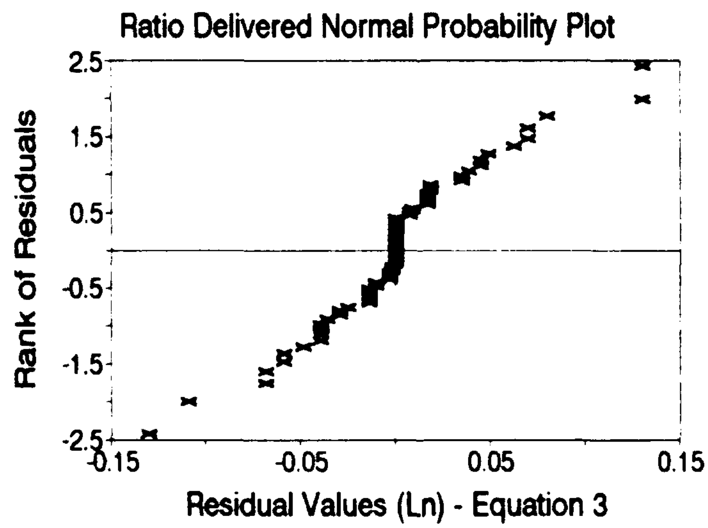
Ratio Delivered Function – Equation 3

$$Ln(\hat{y}) = -0.664018 + (0.643881/2)C + (0.633737/2)G + (0.088493/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	3	13.18458	4.39486	2109.084
Error	60	0.12503	0.00208	
Total	63	13.30961		
R^2 0.990606		Adjusted R^2		0.990137



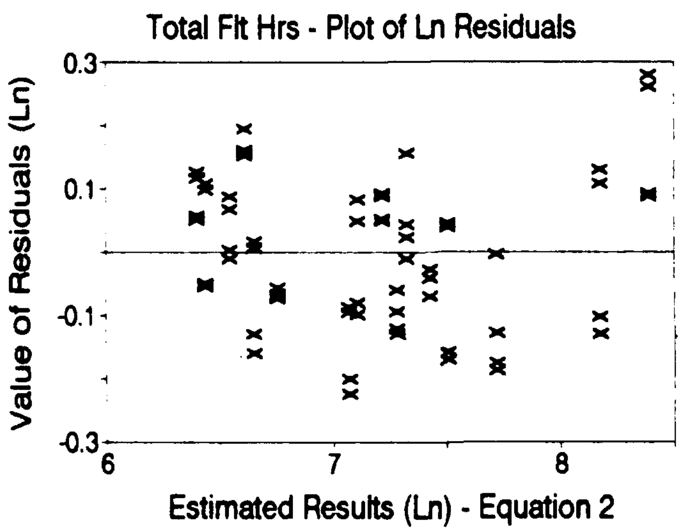


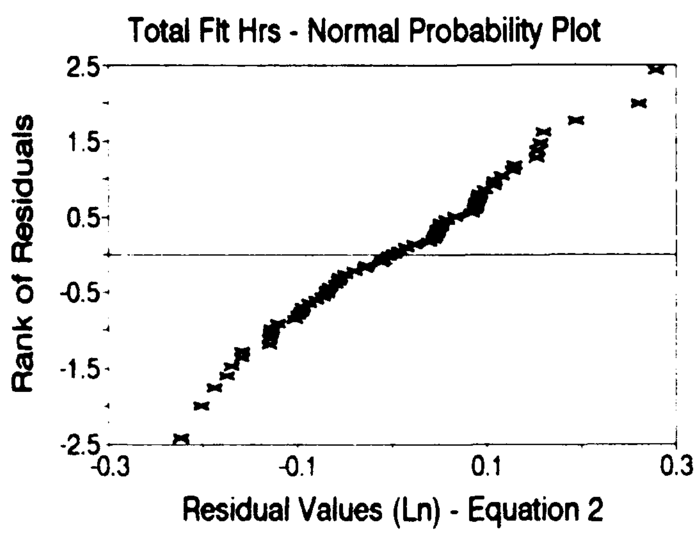
Total Flying Hours Function - Equation 2

$$Ln(\hat{y})=7.163+(0.214/2)A+(-0.501/2)C+(-0.671/2)I+(0.607/2)G +(-0.462/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	5	21.26290	4.25258	295.197
Error	58	0.83554	0.01441	
Total	63	22.08462		
R^2 0.962166		Adjusted R^2		0.958905



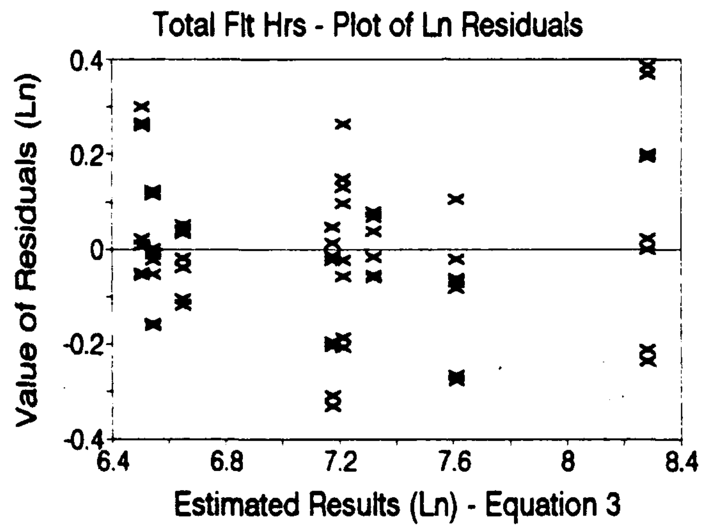


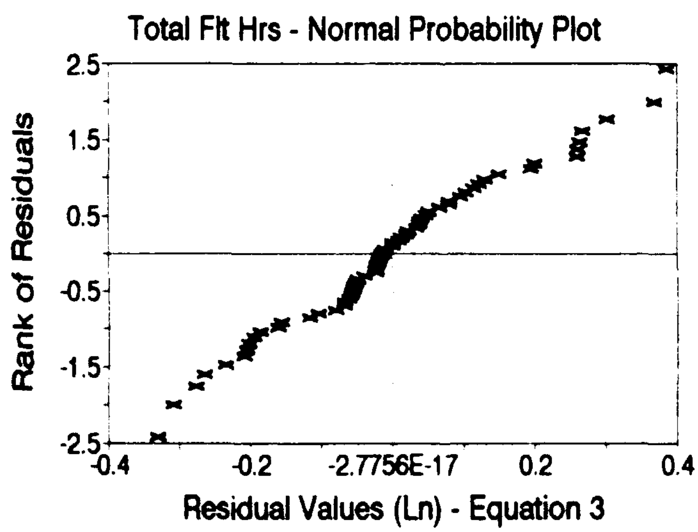
Total Flying Hours Function - Equation 3

$Ln(\hat{y})=7.163+(-0.501/2)C+(-0.671/2)I+(0.607/2)G+(-0.462/2)CG$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	4	20.53016	5.13254	192.756
Error	59	1.57100	0.02663	
Total	63	22.08462		
R^2 0.928864		Adjusted R^2		0.924042



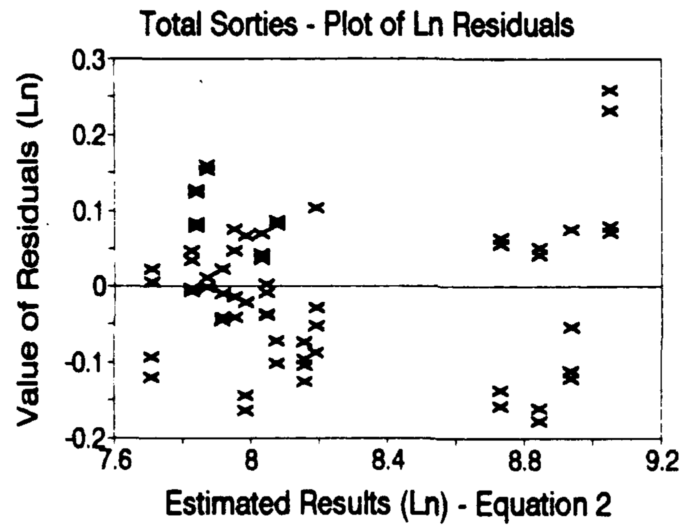


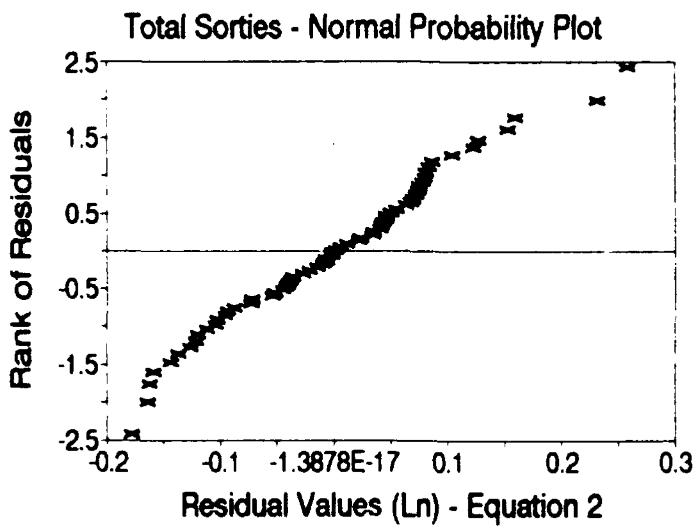
Total Sorties Flown Function - Equation 2

$$\text{Ln}(\hat{y}) = 8.197 + (.205/2)A + (-.526/2)C + (.493/2)G + (.114/2)CI + (-.365/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	5	11.32754	2.26551	228.980
Error	58	0.57385	0.00989	
Total	63	11.90955		
R^2 0.951816		Adjusted R^2		0.947663



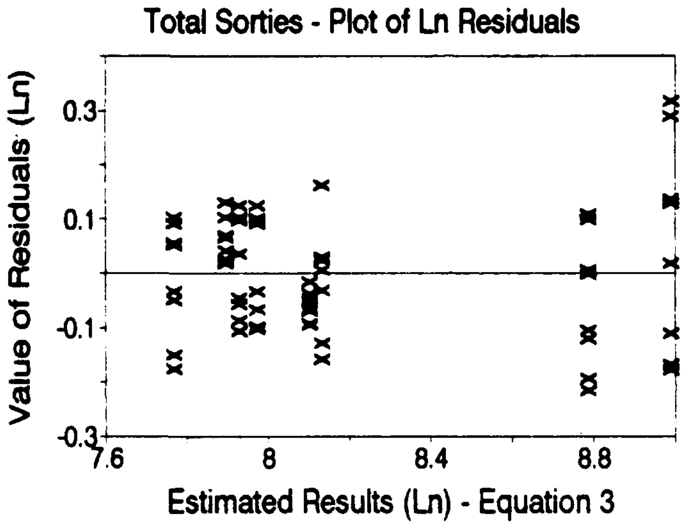


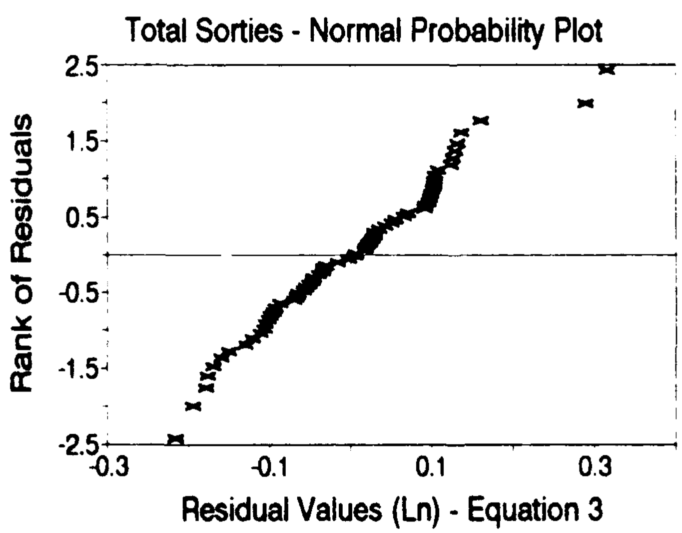
Total Sorties Flown Function - Equation 3

$$Ln(\hat{y})=8.197+(.205/2)A+(-.526/2)C+(.493/2)G+(-.365/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	4	11.11960	2.77990	209.867
Error	59	0.78152	0.01325	
Total	63	11.90955		
R^2 0.934379		Adjusted R^2		0.929930



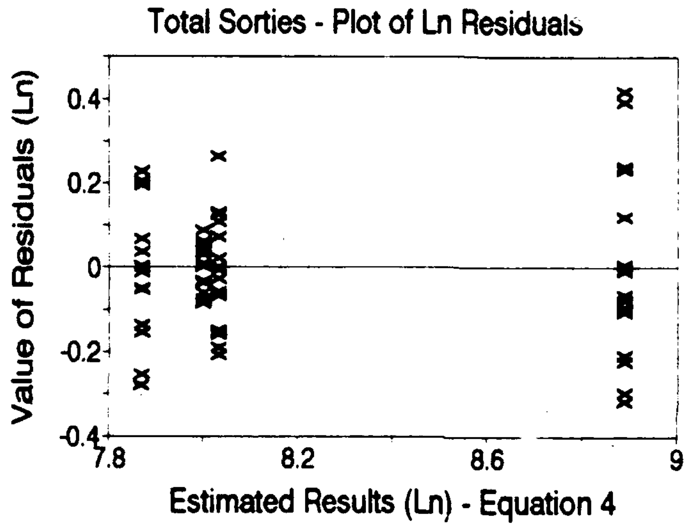


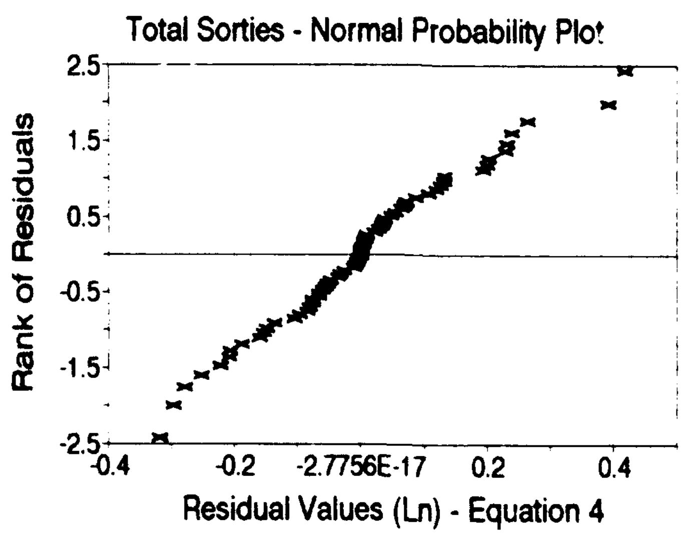
Total Sorties Flown Function - Equation 4

$Ln(\hat{y})=8.197+(-.526/2)C+(.493/2)G+(-.365/2)CG$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	3	10.44720	3.48240	143.802
Error	60	1.45300	0.02422	
Total	63	11.90955		
R^2 0.877997		Adjusted R^2		0.871897



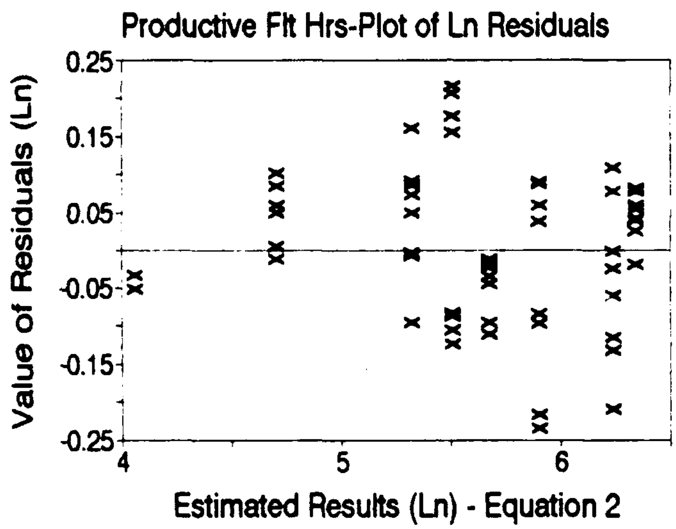


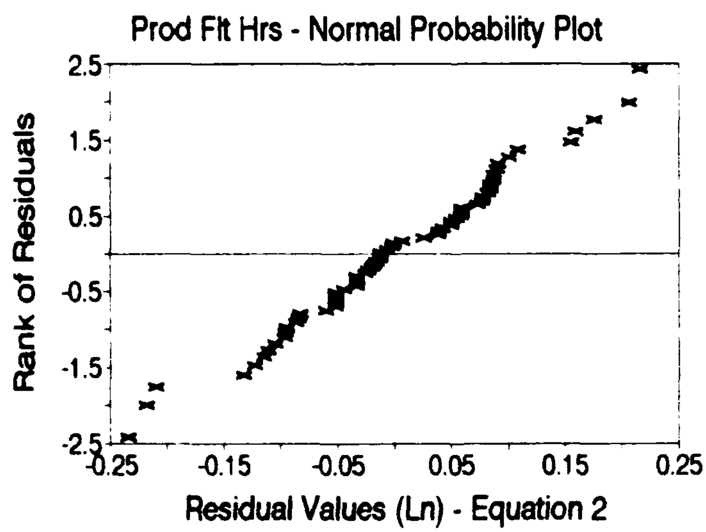
Productive Flying Hours Function – Equation 2

$$Ln(\hat{y})=5.469+(0.778/2)C+(-0.657/2)I+(0.851/2)G+(0.124/2)CI+(-0.547/2)CG+(-0.136/2)IG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	6	33.50744	5.58457	553.353
Error	57	0.57526	0.01009	
Total	63	34.08075		
R^2 0.983121		Adjusted R^2		0.981344



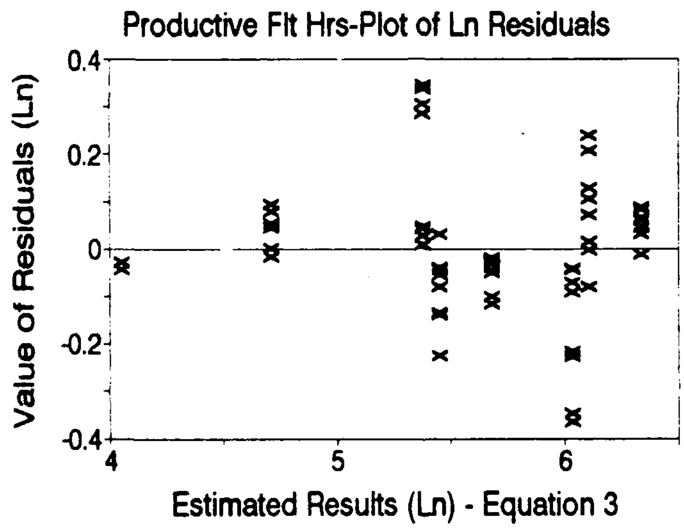


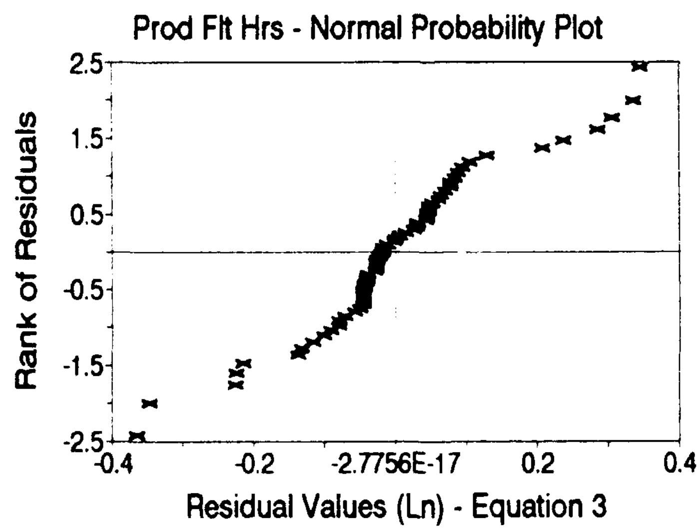
Productive Flying Hours Function – Equation 3

$$\mathrm{Ln}(\hat{y})=5.469+(0.778/2)C+(-0.657/2)I+(0.851/2)G+(-0.547/2)CG$$

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Square	F
Regression	4	32.96549	8.24137	434.984
Error	59	1.11784	0.01895	
Total	63	34.08075		
R^2 0.9672		Adjusted R^2		0.964977



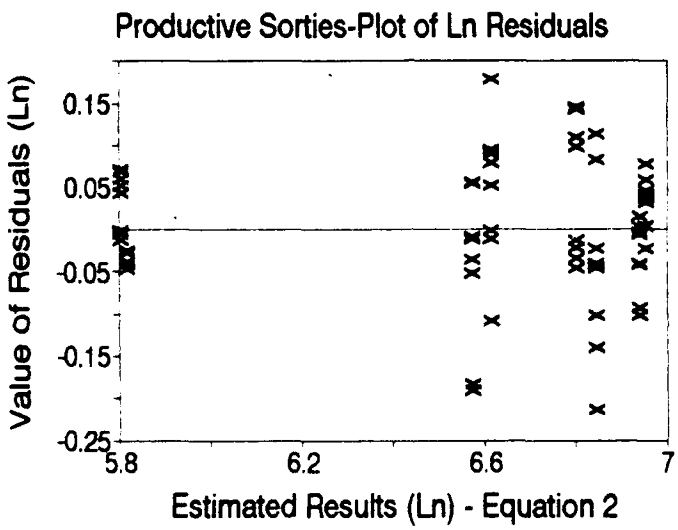


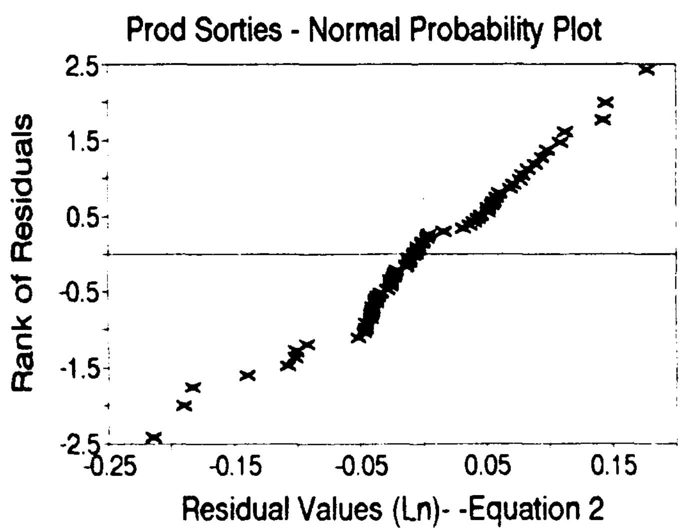
Productive Sorties Function - Equation 2

$$Ln(\hat{y})=6.544+(0.547/2)C+(0.589/2)G +(0.107/2)CI+(-0.122/2)IG+(-0.33/2)CG$$

ANOVA TABLE

Source of Variation	Df	Sum of Squares	Mean Square	F
Regression	5	12.50181	2.50036	380.002
Error	58	0.38163	0.00658	
Total	63	12.88112		
R^2 0.970373		Adjusted R^2		0.9678186



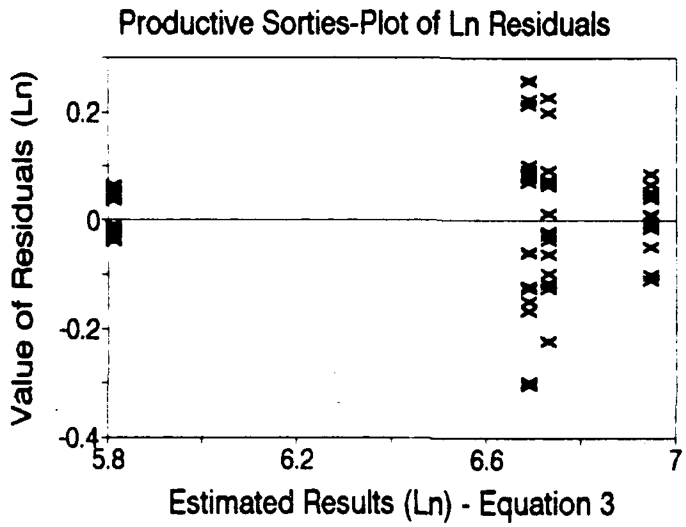


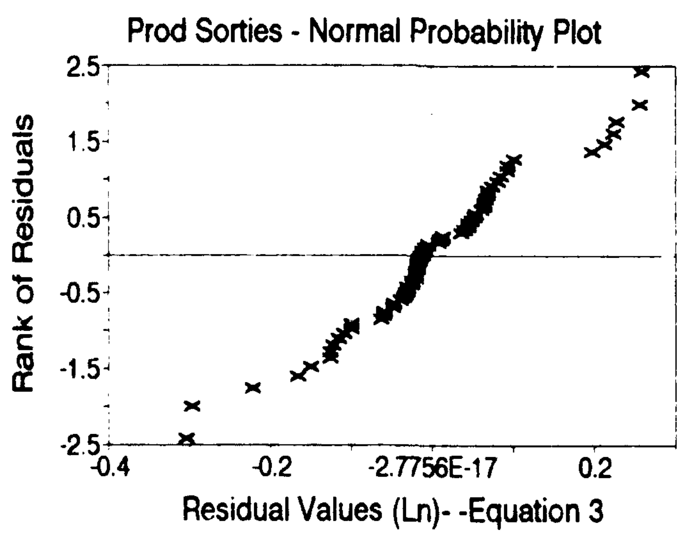
Productive Sorties Function - Equation 3

$Ln(\hat{y})=6.544+(0.547/2)C+(0.589/2)G+(-0.33/2)CG$

ANOVA TABLE

Source of Variation	Df	Sum of Squares	Mean Square	F
Regression	3	12.08048	4.02683	300.056
Error	60	0.80522	0.01342	
Total	63	12.88112		
R^2 0.937489		Adjusted R^2		0.934363





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Vita

Flight Lieutenant Paul Pappas was born in Sydney, New South Wales, Australia on 7 January 1960. He completed his high school education at Phillip College in Phillip, in the Australian Capital Territory, in 1977. In January 1978, he entered the Royal Australian Air Force Academy, at Point Cook in Victoria, where he undertook a Bachelor of Science degree, majoring in Physics, and, later, a Graduate Diploma in Military Aviation. He graduated from the Academy in December 1981, receiving a permanent commission in the RAAF. He then commenced pilot training, graduating and receiving his wings in December 1982. His first flying tour was with Number 37 Squadron at RAAF Base Richmond, in New South Wales, where he flew C-130E aircraft. In January 1986, he was posted to the Officer Training School at Point Cook, where he served initially as an instructor, and later as the school's programming officer. In January 1988, he returned to flying duties with Number 35 Squadron at RAAF Base Townsville in Queensland, where he flew the C-7 DeHavilland Caribou until he was selected to attend the Graduate Logistics Management course. Flight Lieutenant Pappas entered the School of Systems and Logistics, at the U.S. Air Force Institute of Technology, in May 1990.

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REPORT DOCUMENTATION PAGE

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	September 1991	Master's Thesis

4. TITLE AND SUBTITLE AN ANALYSIS OF FIXED WING TACTICAL AIRLIFTER CHARACTERISTICS USING AN INTRA-THEATER AIRLIFT COMPUTER MODEL

5. FUNDING NUMBERS

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Paul Pappas, Flight Lieutenant, RAAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*) This study used computer simulation to identify which tactical airlifter characteristics most significantly affected tactical airlift capability in a given scenario. The Generalized Air Mobility Model was used to simulate a tactical airlift system. Aircraft characteristics within the model were grouped into six variables. A 2^6 two level full factorial experimental design was used to assess the effect of changes in aircraft characteristics on the effectiveness of the tactical airlift system. Yate's algorithm was used to identify significant terms based upon the results of the factorial experiment. These significant terms were used to develop a parsimonious regression model that represented the response function of the experimental variables. The variables remaining in the regression model represented the tactical airlifter characteristics that most significantly affected the capability of the tactical airlift system. Only one scenario was used in the experiment: Central America. This scenario was characterized by a tropical mountainous environment, poor infrastructure, a limited number of major airfields, and many short unprepared airfields. Two groups of tactical airlifter characteristics were found to significantly affect capability of the tactical airlift system in this scenario: the size of the aircraft's cargo bay, and the aircraft's ability to operate on unprepared surfaces.

14. SUBJECT TERMS

Tactical Aircraft, Transport Aircraft, Aircraft Models, Airlift Operations

15. NUMBER OF PAGES 186

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   a. Highly Significant   b. Significant   c. Slightly Significant   d. Of No Significance

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